

6.1 Introduction

In the preceding chapters, the basic data on "ecological" investigations of Iron Age and Roman settlement sites on Voorne-Putten were presented. The interpretation of these data in relation to the location of the sites in the natural environment was discussed in the corresponding chapters. After these reconstructions of environments and related subjects, a major field has remained largely unexplored. This subject, the "palaeo-economy" (cf. Higgs 1975) will be elaborated upon in the present chapter. Although economy may be defined in a very broad sense, in the present study, palaeo-economy mainly focusses on the agricultural sector of the economy. Important fields in this study are amongst others the roles that stock raising and arable farming played and whether an autarkic subsistence economy or an economy involving surplus production and exchange was practised.

To provide a base for the reconstruction of agricultural economies of the sites under review, the following paragraphs supply basic data on crop plants and livestock which played a role in the economies of the sites. The data were obtained from ethnohistorical sources and experimental archaeology, as well as from models for prehistoric situations published by a range of researchers. Subsequently, these data will be elaborated upon in an attempt to draw up models for the agricultural economies of the sites investigated.

6.2 Characteristics of crop plants found in the present study

6.2.1 HULLED, FOUR-ROW BARLEY (*HORDEUM VULGARE* SSP. *VULGARE* FO. *TETRASTICHUM*)

Among the crop plants, barley and wheat (*Triticum* spec.) are the predominant cereals in the Iron Age. In the settlements near the coast of Voorne, dating from the Late Iron Age and Roman Period, barley is of even greater importance and it is virtually the only cereal found in Roman Rockanje.

According to Körber-Grohne (1987), four-row barley is mainly cultivated as a winter crop.

Barley is the least demanding cereal species as far as soil conditions are concerned (Körber-Grohne 1987: 46). In

medieval times, barley and rye were cultivated on artificially drained peaty soils in the western part of the Netherlands (Van der Linden 1956: 68). These soils are probably comparable to the peaty soils on Voorne-Putten. Thirsk (1965: 36) demonstrated that barley was the main crop on peaty soils in sixteenth century Fenlands in Britain, while wheat was of limited importance. Of special relevance is barley's tolerance to salinity. This is confirmed in laboratory experiments by Baykal (1979). He found that the wheat species he studied were more sensitive to salinity than barley, especially four-row barley. Bernstein (1958 cited in Baykal) also reported that a greater salt tolerance was evident in barley varieties compared to wheat varieties.

In salt marsh environments, experiments have been conducted by Körber-Grohne (1967) in Cappelersiel (northern Germany) and by Van Zeist *et al.* (1977) and Bottema *et al.* (1980) in Ulrum near Groningen (northern Netherlands). Both experiments showed that among the cereals, four-row barley is the only cereal that produced reasonable yields in these saline environments, but it could only be cultivated as a summercrop due to flooding in winter.

In Körber-Grohne's experiment, barley showed an input/yield ratio of 1:10. In the ten years' experiments in Groningen, the yield ratio ranged from zero to 1:13.2 (input 175 kg/ha sown in rows; Van Zeist *et al.* 1977). The highest yield corresponds to 2360 kg/ha.

Ripe grains consist for 61-73% of carbohydrates and for 9-12% of proteins. In cool and damp climates, less protein and more carbohydrates are produced than in warm and dry climates. The energy content of barley is 3180 kcal/kg.

6.2.2 WHEAT (*TRITICUM* SPEC.).

The genus wheat embraces several species that can be subdivided into naked and glume wheats, which can both be further divided into several species, each with a different number of chromosomes. In glume wheats, the grains are invested tightly by the lemmas and paleas and they cannot be separated by flailing, whereas naked, free-threshing wheats can.

Glume wheats are predominant in the present material, probably with emmer (*Triticum dicoccum*) being the only glume wheat cultivated (see 4.4.2). Only one probable grain of the naked bread wheat (*Triticum* cf. *aestivum*) was found

in Rockanje. *Triticum dicoccum* was found on the Iron Age sites and -less frequently- in Roman contexts.

Renfrew (1973) mentioned that the majority of emmer varieties grown in Europe is winter-sown. Spring-sown varieties do also exist in Europe (cf. Percival 1921), but, according to Renfrew, the winter forms give heavier yields. Körber-Grohne (1987: 326), in contrast, stated that emmer is sensitive to frost and therefore is mostly cultivated as a summer crop in Germany. Hillman (1981) disclaimed emmer as a summer crop, arguing that wild emmer germinates in the autumn. He further pointed to higher yields in winter crops. In my opinion, the climate in which wild emmer can thrive is highly variable and therefore emmer does not necessarily have to be a winter crop in our regions.

Wheats are the most demanding cereal species in their cultivation as they need a humus-rich loamy soil and are very sensitive to salinity (Körber-Grohne 1987: 28). Renfrew (1973: 66) stated that wheat does not thrive well on loose sandy or peaty soils nor on wet clays, while it tends to lodge when grown in rich, damp bottom land. According to Enklaar (1850), spelt and bread wheat pose higher demands on soil quality than emmer.

The salt sensitivity of wheat species is clearly apparent in the experiments in the Groninger salt marsh. As Bottema *et al.* (1980) concluded neither bread wheat, nor spelt nor emmer were cultivated successfully in three years of trials. This salt sensitivity is also apparent in the laboratory experiments on bread wheat reported by Baykal (1979).

Concerning yields of emmer wheat, the experiments carried out by Reynolds on Butser Farm are of great relevance. The calcareous soil of Butser Farm was in use for pasture prior to the crop experiments. In present-day terms, it is not particularly suitable for arable farming (Reynolds 1987a). Although the soil differs from the soils on Voorne-Putten, it is the only long-term experiment published to date. Van der Veen (1989) started a comparative experiment of yields in locations dispersed all over Great-Britain, but data are not yet available.

In Reynolds' experiments, 61 kg/ha of seed grain was planted in rows at 30 cm intervals. According to him, planting in rows is much more economic than broadcast sowing, as a greater portion of the sowing grain is consumed by birds when the seeds are scattered. Steensberg (1955) stated that sowing in rows only required half the amount of seed as broadcast sowing. Furthermore, hoeing is possible between the rows, which is anything but superfluous because of the weeds.

Harsema (*pers. comm.*) commented upon the large amount of work required to sow more than a few ares (100 m²) of grain in rows. The following calculation may elucidate this point. In Butser Farm, the rows are at 30 cm intervals. In one ha (100 x 100 m), 333 rows of 100 m length each would have to be planted resulting in 33.3 km of rows

per ha. For the Iron Age, Reynolds (1987b: 29) assumed the use of a seed-furrow ard which forms a narrow drill for the seed in the prepared tilth. The Danish Hvorslev and Vebbestrup ards have been used successfully for this purpose on Butser Farm. However, the widespread use of this sophisticated type of ard is still to be substantiated in our area. If in broadcast sowing a strip of 5 m width is sown, the corresponding distance covered on foot would be 2 km per ha. These data are of importance in assessing the time budgets and limits for the prehistoric agricultural economy, which will be discussed in 6.6.4.2.

Reviewing eight years of yields without additional fertilization, Reynolds (1981b) found emmer yields of 400-3700 kg/ha, which corresponds to a yield ratio of 1:7 to 1:59. A steady decline, owing to exhaustion of the soil, could not be observed. Chemical analyses revealed only minor changes in soil structure and nutrient content. Emmer on plots manured with dung showed even higher yields, viz. 3200-4600 kg/ha or 1:51 to 1:74. Interestingly, Reynolds (1987a) demonstrated that modern bread wheat reached a much smaller yield in unfertilized plots, which is attributed to the greater nitrogen demand of modern cultivars. Körber-Grohne (1987: 42) also found that the more primitive crops emmer and einkorn showed higher thousand-grain weights if cultivated on "biological" fields, where no use is made of artificial fertilizers. In contrast, bread wheat, spelt and rye produced higher thousand-grain weights if fertilized with mineral nitrogen.

All things considered, the yields in Butser Farm never dropped below 1:7. Worth mentioning is that spring sown emmer does about as well as winter sown varieties (Reynolds 1987a). Reynolds also reported on a one year's trial on first class arable soil near Fishbourne. Here, the yield for (winter sown) emmer was 1:91 (ca. 5700 kg/ha).

Slicher van Bath (1987) provided data on often quoted yields in medieval times when the average fluctuated between 1:2 and 1:3. However, as he also observed (1987: 194-196), some farms did produce significantly higher yields. In northern France (Artois), the average yield in 2 x 9 years was about 1:10 in the 14th century, and never below 1:7.3. He attributed this to a more efficient organisation, these farmers sowed 141 litres per ha, where in other places 200 liters per ha were sown. He suggests that planting was probably done in rows, thus explaining the lower amount sown.

Of similar importance as the method of sowing is an observation put forward by Mercer (1981). According to him, the medieval yield data have often been questioned because they were used for purposes as rental, tithe and tax assessments. Farmers therefore had a reason to keep their official yields low. Kohl (1948: 114) lively illustrated the same practice for the 19th century. As shown in the minutes of the agricultural society of 1878, it was still common

practice among farmers to estimate yields far too low, knowing the positive influence on the taxes to be paid.

Reynolds' experiments indeed suggest that prehistoric wheat yields may be estimated higher than Slicher van Bath's data indicate. In view of Reynolds' data, and those from Artois in Slicher van Bath's publication, a yield of 1:7 in prehistoric times will be regarded as a lower limit.

According to Körber-Grohne (1987: 326), emmer grains consist for 55-61% of carbohydrates and for 15-21% of proteins. The protein content is considerably higher than the 10-13% of modern bread wheat. The calorific value of emmer is unknown to me, that of bread wheat is 3300 kcal/kg.

6.2.3 BROOMCORN MILLET (*PANICUM MILIACEUM*)

The last cereal species dealt with in the present study is millet. Its importance on Voorne-Putten is considerably less than that of barley and wheat, as it occurs on only one site, and in only one sample. Remarkably, *Panicum* occurs regularly on west European Iron Age and Roman sites outside Voorne-Putten (cf. Bakels 1991; Knörzer 1991).

Millet is very sensitive to frost and thus an obligate summer crop, sown in mid-May (see also Enklaar 1850).

Von Lengerke (1840 cited in Körber-Grohne 1987: 331) indicated that millet is the most appropriate crop for a sandy soil, as well as for peat. Columella stressed the importance of a humid soil to millet (Ahrens 1972: 84). Heresbach basing himself on classical authors, stated that *Panicum* favours a damp, marshy soil, while dry and calcareous soils are disliked (cf. Dreitzel 1970). Unfortunately, these observations apply to the Mediterranean area, as do all other classical communications on agriculture. Bottema *et al.* (1980) concluded that millet cannot be grown in brackish surroundings. Data on yields of *Panicum miliaceum* are unknown to me.

Körber-Grohne (1987: 331) gave the following components of millet: 11-14% water, 68-72% carbohydrates, 10-11% proteins, 2-5% fat, 0.7-2.4% minerals and 0.6-2.1% fibres.

6.2.4 OATS (*AVENA SATIVA*)

It is highly questionable whether oats were cultivated on Voorne-Putten during the Iron Age and/or Roman Period. On the basis of flower bases, only *Avena fatua* has been attested with certainty. The twisted awn fragments most likely originated from this species too¹. If oats did play a role in the economy of any of the sites, it must have been a very subordinate one.

Oats are sensitive to frost, so they are cultivated as a summer crop in western Europe.

In northern Germany, they are cultivated on heavy clay in the coastal area (Körber-Grohne 1987). Cultivation of oats

in the salt marsh area of northern Groningen was relatively successful.

6.2.5 LINSEED OR FLAX (*LINUM USITATISSIMUM*)

The remains of linseed/flax found in the present study suggest the use of the oil-rich seeds for consumption (see also 4.4.4). Whether the stems were also used for flax-fibres could not be demonstrated. It is assumed that linseed was of nutritious value for the former inhabitants of Voorne-Putten.

Linum is usually cultivated as a summercrop, although a winter-sown variety exists as well (Körber-Grohne 1987: 367).

Linseed, cultivated for the oily seeds, favours warm, dry climates, whereas flax for fibres grows best in temperate, damp climates (Körber-Grohne 1987: 366-372). Although would this suggest a cultivation for fibres in western Europe, this is not corroborated as clearly in the archaeological record.

According to Renfrew (1973), *Linum* is best suited to fertile, deep, well-drained loams. Light soils are unsuited to seed flax, particularly in areas of deficient rainfall. Seegeler (1983) stated that the only soils unfit for linseed cultivation are dry sands, wet and compact clays, and marshy or very acid grounds (see also Gregg 1988: 78). Flax is reported to be a poor competitor with weeds. It is usually necessary to weed one to three times.

Seed yields can range to 800 or even more than 1000 kg/ha in unmechanized cultivation in Ethiopia (Seegeler 1983: 186). The experiments in the Groninger salt marsh revealed that flax can be cultivated with success in such environments, although the next oil crop to be discussed, *Camelina sativa*, produces even better results (Van Zeist *et al.* 1977; Bottema *et al.* 1980). In Ulrum, the yield ratio varied between zero and 1:14.5. The highest yield corresponds to 1175 kg/ha. In Cappelsiel, *Linum* yielded 1:3.9 in a plot with less storm flood damage.

According to Körber-Grohne, the seeds consist of 6-14% water, 22-44% oil, 17-31% proteins and 18-29% carbohydrates. The oil contains 17-31% of linoleic acid, an essential fatty acid. To use this valuable seed content, the seeds must be broken as the thick wall cannot be digested.

The calorific content of *Linum* is unknown to me as well as to the Dutch *Instituut voor Levensmiddelentechnologie* (Landbouw Universiteit Wageningen).

6.2.6 GOLD OF PLEASURE (*CAMELINA SATIVA*)

Gold of pleasure is the second crop cultivated for its oily seeds. It is a summer crop which already can be harvested 12 to 14 weeks after sowing. This makes it an ideal substitute for frozen winter crops (Körber-Grohne 1987).

Camelina sativa does not pose high demands on soil quality, it can still be grown on dry, sandy soils, although it

favours a sandy, calcareous loam. Plessers *et al.* (1962) stated that although *Camelina* will grow on most soils, it is not recommended for heavy clay or peaty soils. An important characteristic of gold of pleasure is its tolerance for salinity.

As the experiments by Körber-Grohne (1967) and Van Zeist *et al.* (1977) showed, *Camelina* is the crop most resistant to salt, producing yield-ratios of 1:13 to 1:20 in Cappelsiel. In northern Groningen, the ratios were between 1:25.5 and 1:57.5, which corresponds to 690-1555 kg/ha. During two years with extensive flooding during the seedling stage, all the crops, including *Camelina*, failed in Ulrum.

The seeds consist of ca. 27% oil, 17% proteins and 17% carbohydrates (Körber-Grohne 1987: 391). According to Plessers *et al.* (1962), ca. 91% of the fatty acids in *Camelina* is unsaturated and among other things consist of 16.4% linoleic acid. The calorific content of gold of pleasure seeds is unknown to me and the Dutch *Instituut voor Levensmiddelen-technologie* (Landbouw Universiteit Wageningen).

6.2.7 RAPE (*BRASSICA RAPA*)

Rape is the last potential oil seed crop found in the present study. It is mainly present in the Early Iron Age site of Spijkenisse 17-30. Collection of the seeds from wild plants cannot completely be ruled out. Rape is normally grown as a winter crop (Körber-Grohne 1987: 162)

According to Körber-Grohne (1987), rape can be cultivated on poor, light soils. It is also more or less salt tolerant. Bottema *et al.* (1980) showed that *Brassica rapa* has a reasonable yield as a summer crop in the salt marsh environment, up to 1:28.3, corresponding to 805 kg/ha.

According to Körber-Grohne (1987: 149), rape seeds consist of 32-50% oil, 16-27% proteins and ca. 23% carbohydrates. According to Plessers *et al.* (1962), the fatty acids consist for 97% of unsaturated fatty acids, among which ca. 15% is linoleic acid. The calorific content of the oil is ca. 9000 kcal/kg (*Voorlichtingsbureau voor de Voeding* 1980).

6.2.8 CELTIC BEANS (*VICIA FABA* VAR. *MINOR*)

Seeds of Celtic bean were only discovered in some samples from the native Roman settlement Nieuwenhoorn.

The plants are more frost-tolerant than most other cultivated leguminous crops, but they freeze at temperatures below -4°C. They require humid conditions, so they are sown early in spring (February-March).

Körber-Grohne (1987 citing Fruwirth 1921) further stated that heavy clayey or peaty soils are best suited for the cultivation of Celtic beans. Calcareous or sandy soils are only suitable if the precipitation is sufficiently high.

The experiments in Cappelsiel and Ulrum have demonstrated Celtic beans growing successfully in most years at the salinity conditions prevailing there. In years in which the crop was flooded in an early stage of development, no yield

could be obtained in Ulrum. In more favourable years, the yield could reach 1:16.5, corresponding to 4240 kg/ha (Bottema *et al.* 1980). According to Enklaar (1850), in less extreme situations Celtic beans yielded 1:16.7 to 1:32 if planted in rows, broadcast sowing in contrast almost halved the yields.

According to Körber-Grohne, ripe seeds of Celtic bean consist among other things of 25.3% proteins, 48.3% carbohydrates and 1.7% fat. According to the *Voorlichtingsbureau voor de Voeding* (1980), fresh (unripe) Celtic beans contain 360 kcal/kg, whereas dried beans (*Phasaeolus*) contain 2700 kcal/kg. The calorific content of ripe Celtic beans may also be this high.

6.3 Characteristics of livestock

For the review on livestock, three publications were mainly consulted. Prummel (*in press*) discussed the bone remains of Iron Age sites on Voorne-Putten (see further *ch.* 5). IJzereef (1981) published data on the basis of his investigation on Bronze Age animal bones found in Bovenkarspel, in the northwestern part of the Netherlands. Gregg (1988) published data gathered from a wide range of references of relevance to the neolithic situation modelled by her. It should be noted that the sizes of domesticates changed through prehistoric and historic times; Neolithic cattle is larger than Bronze Age cattle, which is in turn somewhat larger than that of the Iron Age (Clason 1967). IJzereef's and Gregg's data should thus be treated with caution.

6.3.1 CATTLE (*BOS TAURUS*)

Cattle provide a potential source of meat, milk and leather, they can be used as traction units and the bones can be made into implements. According to Van Wijngaarden-Bakker (1988), cattle is reasonably well adapted to damp soil conditions.

Characteristics of the life cycle of cattle have been provided by Gregg (1988). Weaning takes place after ca. 200 days and heifers of unimproved breeds of cattle normally calve when they are 3.5 to 4 years old. Gregg further stated that although cattle do not have a specific breeding season, a calving season can be created by allowing bulls access to cows only for a restricted period. According to her, there are particular advantages to a late winter/early spring calving season. The cows are stalled over winter, so they can be watched and may be helped in calving if necessary. Besides, cows provide more and better milk on spring and summer pastures than on autumn pastures and winter fodder. Thirdly, spring calves will be weaned by the start of winter, with a high body weight, so well-prepared to withstand the winter.

According to Gregg's references, 80% of the mature cows calve and, of the calves born, 20% do not survive to weaning. IJzereef (1981: 37) assumed that 30% of the cows

do not give birth or give birth to a calf that dies in infancy, while Gregg's data correspond to a figure of 36%.

Prummel (*in press*) assumed a meat supply of 100 kg for mature Iron Age cattle, which corresponds to a live weight of ca. 200 kg. IJzereef determined live weights of Bronze Age cattle with the aid of several extrapolations from bone weights. He concluded an average of ca. 200 kg for adult cattle, and ca. 100 kg for 2-3 year old heifers. Reichstein (1984) assumed a live weight of 150-250 kg for cattle in northern Germany during the Iron Age and Roman Period. Since slaughter of younger animals did play an important role in the investigated sites (see *ch. 5*), IJzereef's data are the most appropriate as he provided data for several age-classes. His data are more or less applicable to the situation on Voorne-Putten, in view of the similar estimated weights for adult cattle.

IJzereef (1981) assumed that the amount of usable meat is 30% in adults and 40% in calves. In addition adults yield 20% fat. For 1-3 year old cattle, the fat yield amounts to 15% and for 0-1 year old individuals to 10%. Furthermore, IJzereef also assumed an additional 10% of the live weight for blood, organs, brains, intestines and bone marrow. IJzereef took the calorific value of meat to be 1430 kcal/kg for calves and 1970 kcal/kg for adult cattle. He assumed a calorific value for fat of 8000 kcal/kg, the 10% "rest" is estimated at 2000 kcal/kg.

If IJzereef's data are used to calculate the energy provided by an adult head of cattle (of 200 kg!), 60 kg of meat (1970 kcal/kg), 40 kg fat (8000 kcal/kg) and 20 kg organs (2000 kcal/kg) result in 478,200 kcal. According to IJzereef's data, a 1-3 year old head of cattle (heifer) weighs 80 kg, of which 35% is meat (1700 kcal/kg), 15% is fat (8000 kcal/kg) and 10% forms the remaining edible component (2000 kcal/kg). The total calorific output thus is 159,600 kcal. According to Gross *et al.* (1990), the protein content of beef is 168 g/kg. The protein content of veal is 200 g/kg (*Voorlichtingsbureau voor de Voeding* 1980). The proteins provided by one adult head of cattle amount to 16.8 kg and by a heifer to 5.6 kg.

Prummel (*in press*) assumed a yearly milk production of 100 kg per cow as an average for all cows. Haarnagel (1979) assumed that the surplus of milk was 600 kg/year during the Roman Period. He based this assumption on recent data from Balkan cattle that are also small and living under comparable environmental conditions. The above shows that milk production is difficult to quantify. Prummel's data will be used here to obtain a minimum value. IJzereef and Gross *et al.* (1990) set the energy content of milk at 600 kcal/kg. The protein content of milk is 30 g/kg (Gross *et al.* 1990).

Van Wijngaarden-Bakker (1988) noted that cattle primarily have a grazing strategy of feeding, which implies that they need food with a high nutritional value, mainly grasses. They are specialised in digesting unignified cell walls, in contrast to browsers such as goats, which can digest woody

tissues. Of great interest in relation to cattle is the research in the Dutch "*Oostvaardersplassen*" by Drost (1986). The vegetation of this area predominantly consists of reedlands, with small patches of more grassy terrain with *Poa trivialis*. Ruderal areas with nettle (*Urtica dioica*) and thistle (*Cirsium arvense*) and shrubs occur. Drost's investigations demonstrated that grasses are the main food suppliers in spring and autumn, while reed (*Phragmites australis*) is the main food in summer. After the end of December, the cattle has to get additional food, since they appear not to eat dead reed. They can only eat twigs then which do not provide enough energy.

Interestingly, Drost (1986: 28) observed that cattle grazing in reedlands caused an increase in plants of ruderal situations. In particular these plants are of important nutritious value in autumn, when reed cannot be digested by cows any longer.

Gregg (1988) provided details on winter fodder requirements for domesticates, on the basis of observations on recent animals. She stated that the share of straw in winter fodder may not exceed 40% of the diet. Barley straw, however, may constitute ca. 80% of the fodder of present-day beef cows (Reynolds *pers. comm.*). Straw was not found in the byres of the excavated farms on Voorne-Putten during the Iron Age and Roman Period. Thus, straw was not used as winter fodder for the stalled animals on such a scale that we still find traces. Instead, reed stems (*Phragmites australis*) occur abundantly. Most probably, the reed was not only used for litter but also for food. Drost (1986) demonstrated that reed may indeed serve as food for cattle, but the dead winter stems are not palatable. During July to September, the calorific value of reed stems is even higher than that of other grasses.

The fact that seeds of plants that decay easily in autumn (e.g. *Lychnis*, *Lythrum*) are very commonly associated with the reed stems found in the material from Voorne-Putten indicates that they were harvested before the winter. Twigs do not occur on any appreciable scale in the layers of dung in the byres of the excavated farms. Apparently, leaf hay was not used extensively for fodder, which is not surprising in view of the scarcity of trees around the settlements. Green, dried reed with many other herbaceous plants will have formed the dominant part of the winter fodder on Voorne-Putten.

Gregg quoted a requirement of 400 kg of hay per head of cattle per month in a recent Alpine village, Reynolds (1987b) suggested 450 kg. Gregg's Neolithic cows were assumed to weigh 400 kg, whereas Prummel, IJzereef and Reichstein arrive at ca. 200 kg for Iron Age cattle. Reduction of the requirements proportionally, would produce figures of 200-225 kg of hay per adult head of Iron Age and Roman cattle per month. It is assumed here that this hay requirement was mainly fulfilled by dried reed mixed with

forbs. The animals will have been stalled for four months of the year at maximum, so 800-900 kg of reed is required per head of cattle. Shorter stalling-periods can be imagined as well, it could even be defended that the byres were only used when the fields were covered by snow. The hay requirements would be less. The amount of hay needed for four months will be the basis of the calculations in this chapter. If the farmers could harvest a four months' hay requirement, a smaller requirement would definitely have been manageable.

Slicher van Bath (1987: 325) stated that an adult cow requires 1.5 ha for summer- and winterfodder if grazing occurs exclusively on grassland. IJzereef assumed 1 ha for Bronze Age cattle, Fokkens (1991) based himself on other references and also arrived at 1 ha per year and the same area for two calves per year. According to Drost, four to ten heifers could graze on 20 ha of reedland. This figure (2-5 ha per animal) is used here for the adult Iron Age cattle (with comparable weight). In the eight months that cattle were not stalled, they probably required 8/12 of 2-5 ha = 1.3-3.3 ha per head. In salt marsh conditions, one adult head of cattle can graze on 1 ha during six months (Ooster-veld *pers. comm.*). The smaller Iron Age cattle may have required 1 ha of salt marsh per head per year. Again, these low numbers of cattle per area will be used here to explore potential limits for the economy, in this case in land requirements.

6.3.2 SHEEP AND GOATS (*OVIS ARIES* AND *CAPRA HIRCUS*)

Sheep and goats are difficult to distinguish in palaeozoological studies (see 5.2.1). Prummel's data suggest that probably only sheep occurred, at least in the Iron Age, on Voorne-Putten. On the other hand, the droppings in the native Roman settlement Nieuwenhoorn 09-89 contained *Myrica gale* remains. For the Iron Age site of Assendelft Q, droppings containing *Myrica* have been conceived as evidence for goat, since sheep strongly dislikes the bitter taste of bog myrtle (see 5.2.1). The identifiable sheep/goat bones in Assendelft all belonged to sheep (Van Wijngaarden-Bakker 1988), as on Voorne-Putten. The latter author suggested that this discrepancy between botanical and zoological evidence could be explained by assuming that the goats were primarily kept for their milk production. This would result in few animals being slaughtered. The use of goats mainly for their skin, which is very easy to work up (Groenman-van Waateringe *pers. comm.*), may also explain the absence of bones in the farms themselves. Besides, Van Wijngaarden-Bakker (1988: 161) also stressed the sensitivity of goats to coldness. This will also have necessitated the indoor housing of goats, which was much less urgent for sheep. IJzereef (1981) also assumed that sheep were only rarely to be found in byres.

Sheep and goats may have provided the inhabitants of

Voorne-Putten with meat, milk, wool (or hair), fleeces and bones. As for cattle, Gregg (1988) reviewed characteristics of sheep and goats. In temperate regions, the breeding season of caprovids, which is controlled by photoperiodicity, occurs primarily in September/October. The age of first parturition is normally at two years. Ewes and does can be expected to bear young for up to eight years. Gestation lasts for five months, lambing and kidding normally takes place in February or March. Does frequently bear twins, ewes usually have single births.

According to Van Wijngaarden-Bakker (1988), sheep are grazers and goats are browsers. According to Reynolds (1987b), however, the primitive sheep of Soay in Butser Farm prefer browsing leaves to eating grass.

Van Wijngaarden-Bakker further stated that sheep are reasonably well adapted to damp soils. However, the liver-fluke mainly occurs in damp environments, so dry (or saline) places are much more favourable to sheep. Goats are highly sensitive to damp conditions.

IJzereef assumed the meat weight to be 30% of the live weight. He estimated live weights from the bone weights of his Bronze Age material. For sheep, he arrived at a weight of 20-34 kg, with an average of 27.4 kg. One goat metatarsus corresponded to an animal with a live weight of 33.3 kg. In modelling Bronze Age economy, IJzereef subsequently assumed a live weight of 30 kg for both sheep and goats. Reichstein (1984) assumed a live weight of 30-50 kg for sheep in northern Germany during the Iron Age and Roman Period. Prummel (*in press*) calculated with a meat supply of 20 kg for adult sheep.

IJzereef assumed 2930 kcal/kg for both sheep and goat meat. Apart from meat, IJzereef also included fat in his calculations; for sheep/goats fat is set at two-thirds of the meat weight, with a calorific value of 6000 kcal/kg. IJzereef estimated all the other edible components at 10% of the body weight, with 2000 kcal/kg. Thus a sheep/goat of 30 kg yields 9 kg of meat (2930 kcal/kg), 6 kg of fat (6000 kcal/kg) and 3 kg of other edible components (2000 kcal/kg). The total amount of calories thus is 68,370 per slaughtered sheep/goat. It is assumed here that a lamb yields 30% of the calories of an adult, as in cows. Thus, one lamb yields 20,500 kcal. The proteins amount to 190 g/kg for lamb, so one lamb yields 0.5 kg of proteins.

According to Gregg, the lactation for unimproved breeds is ca. 135 days for sheep and ca. 210 days for goats. An average daily production of 0.33 l for sheep and 0.38 l for goats (during the lactation period) is based on data from sheep of 40 kg and goats of 35 kg. Gregg assumed that milk productivity varies in proportion to body weight. If IJzereef's 30 kg is assumed, the yearly milk production totals 34 l for sheep and 69 l for goats. The lesser production of milk by sheep is partly offset by the calorific content; sheep milk contains ca. 1000 kcal/kg, goat milk only ca. 700

kcal/kg. Prummel assumed a milk production of 50 litres for Iron Age sheep.

The grazing and fodder requirements for three mature sheep or goats is equal to that of one present-day cow (Oosterveld *pers. comm.*). The live weights of sheep and goats do not differ strongly between Neolithic and Iron Age or Roman individuals. In view of the fact that sheep most probably were kept outside throughout the winter, the requirements per head may have been 0.7-1.7 ha for grazing. Sheep probably could not graze in wet, natural reedlands surrounding the farms. When cattle, which are rough grazers, graze in such reedlands, vegetation becomes more suitable for grazing by sheep, which are fine grazers. This situation is directly comparable to the situation in the Serengeti in Africa. The migration routes of the fine grazers, in this case gazelles follow that of rough grazers (zebras).

In salt marsh environments, three sheep require 1 ha for six months of grazing (Oosterveld *pers. comm.*).

Since sheep can winter outside, their role in the diet is difficult to assess. The subordinate role of sheep/goat bones relative to those of cattle, however, indicates their smaller dietary importance.

6.3.3 PIGS (*SUS DOMESTICUS*)

Although pigs in contrast to cattle and caprovids do not provide the renewable resource of milk, they have another value as well as providing pork. As Gregg stated, by consuming rotting vegetables, crop wastes, stable scraps and carrion as well as human and animal excrements, pigs provide some means of controlling refuse in settlements. That they convert this debris into pork is an added bonus (Gregg 1988: 118). Due to their high reproductive rate, pigs are a very elastic resource, in times of shortage many pigs may be slaughtered, whereas in years of plenty, slaughtering may have been much less.

The following data for pig's a life cycle have been provided by Gregg. Breeding mainly occurs in late October to early November, farrowing is in early spring. A litter size of five or six is the norm. Sows usually farrow for the first time when they are one year old and they can continue to breed for another six years. IJzereef (1981) also assumed a litter size of six, but Prummel (*in press*) based her calculations for Iron Age pigs on a litter size of only two. The low share of pig bones indicates its small importance, and this low estimate will be followed here. It cannot be excluded that more piglets were slaughtered than is suggested by the faunal remains, as their less calcified bones may decompose more easily. The estimates published by Prummel thus provide minimum values.

According to Van Wijngaarden-Bakker (1988), the pig is very well adapted to damp soil conditions.

Pigs attain much of their body weight after the second summer. The weight of mature Neolithic pigs is assumed to

be 30 kg (Gregg 1988). A significantly higher weight is estimated by IJzereef for Bronze Age pigs, viz. 75 kg. He assumed a meat yield of 30% of the live weight, i.e. 22.5 kg. Prummel (*in press*) based her calculations on a meat yield of 20 kg for adult pigs and 10 kg for piglets. Reichstein (1984) assumed a live weight of 40-60 kg for mature pigs during the Iron Age and Roman Period.

According to Gregg, the energy content of pork is 2450 kcal/kg, IJzereef assumed 2800 kcal/kg. IJzereef further assumed a fat yield as high as the meat yield, with an energy content of 6000 kcal/kg. Other edible parts in pig are supposed by him to amount to 20% of the live weight with 2000 kcal/kg. Thus an adult pig according to IJzereef yields 22.5 kg of meat (2800 kcal/kg), 22.5 kg of fat (6000 kcal/kg) and 15 kg of other edible components (2000 kcal/kg), totalling 228,000 kcal. Gregg's data suggest a total energy yield of only 36,750 kcal (16% of IJzereef's pigs). Gregg's data seem too low and IJzereef's data will be used here. Unfortunately, IJzereef does not provide data for piglets, which according to Prummel (*in press*) constituted ten percent of the slaughtered pigs on the sites on Voorne-Putten. In the present study, a live weight of 20 kg is assumed, and a meat yield of 40% (analogous to calves), with 72.5% of the calorific value of adult meat, as in IJzereef's cattle, i.e. 2000 kcal/kg. Thus, meat provides 16,000 kcal per piglet. IJzereef assumed that calves provide half the fat yield of adult cattle, for piglets this would correspond to 15% of the body weight, with an energetic value of 6000 kcal/kg. This results in a fat yield per piglet of 18,000 kcal. The remaining edible components may be set at 20% as in adult pigs. With an energy content of 2000 kcal/kg, this yields another 8000 kcal. Thus, one piglet may be equivalent to an energy supply of 42,000 kcal.

The pigs most likely did not need straw/reed or hay on a large scale as they will usually have been fed domestic waste.

The above-mentioned data are necessary for calculating the total area of land required by the inhabitants on Voorne-Putten during the Iron Age and the Roman Period if the total food supply was obtained from the area itself. A comparison with the available area may subsequently give insight into the possibility of such a food supply. The area needed and the feasibility of these calculations will be included in the following paragraphs.

6.4 The evidence for the cultivation of crops on Voorne-Putten during the Iron Age and the Roman Period

6.4.1 THE LOCATION OF THE ARABLE FIELDS

The palynological investigations (see *ch. 2*) have revealed that relatively dry, mineral soils with riverbank forests (German: *Auenwälder*) were present along the Meuse. Clearings occurred in these forests during the Early Iron Age. Particularly oaks declined considerably. The analysis of

wood remains from the excavated sites on Voorne-Putten revealed that these oaks were not extensively used for building purposes (see *ch.* 3). For what reason could these clearings on the levees have occurred? The macroremains of the investigated sites offer clues to this problem. All are typical for summercrops, while weeds characteristic of wintercrops are completely absent. Although Groenman-van Waateringe (1979) claimed that wintercrop weeds do not occur before the Roman Period, later investigations have demonstrated these wintercrop weeds for the Iron Age. The exclusive occurrence of summercrop weeds seems to be limited to the coastal area. Wintercrop weeds occur very regularly in samples analysed from at least six Iron Age sites on Pleistocene soils (unpublished data obtained in the palaeo-botanical laboratory of the *Instituut voor Prehistorie, Leiden*). Thus, the exclusive occurrence of summercrop weeds on Voorne-Putten is rather significant. Cultivation of crops on the deforested levees along the Meuse may explain this exclusiveness of summercrop weeds. The flooding of the levees during winter, which will have been a normal occurrence, prevented the cultivation of wintercrops. Thus, only summercrops could be cultivated, and only summercrop weeds could develop. Bannink *et al.* (1974), however, observed that on rich clayey soils in the coastal area, no wintercrop weeds occur in winter-sown crops due to the richness of the soil (see also Van Haaster 1985). Therefore, the cultivation of wintercrops cannot be ruled out completely, but the import of crops from sandy Pleistocene soils can be excluded, as the associated wintercrop weeds would have been imported too.

Among the cultivated crops found on Voorne-Putten, wheat and barley are the main cereals, whereas linseed and gold of pleasure are important crops with oil-rich seeds. Leguminous crops, like pea and Celtic bean, have not been demonstrated for the Iron Age. This must probably be attributed to the very small possibility of these seeds becoming carbonized and the fast decomposition of the uncarbonized seeds (see further 4.4.7).

The cultivation of crops on the levees along the Meuse has been made plausible above but any cultivation of crops on the peaty soils around the settlements must also be considered. An important question is whether some of the crops could be cultivated on the peaty soils which surrounded the farms, at least those of the Early and Middle Iron Age, or whether they would require the mineral soils such as found on the levees. On the basis of agricultural information (see 6.1), the following deductions can be made about cultivation on peaty soils. The cultivation of barley on artificially drained peat during medieval times in the western part of the Netherlands demonstrates that growing of barley on peat cannot be excluded. The other important cereal, wheat, was not cultivated on drained peat in medieval times (see also Thirsk 1965: 36). The third cereal,

broomcorn millet, can be cultivated on peat. Most significantly, however, this cereal is only found in one sample from Spijkenisse 17-30.

The oil-rich seeds of linseed cannot be grown on marshy or very acid soils (Seegeler 1983). The peat around the sites thus probably was unsuitable for growing linseed. Gold of pleasure can be grown on most soils, but again peaty soils are not recommended (Plessers *et al.* 1962). Whether rape-seed can be cultivated on peaty soils is not certain. Thus, when these considerations are reviewed, it can be concluded that probably only barley and millet were suitable for cultivation on peat in the vicinity of the Early and Middle Iron Age sites.

During the Late Iron Age and the Roman Period, the environmental conditions differed to a considerable extent (see 1.2.1). The presence of clayey sediments deposited during the Dunkirk I transgression phase will certainly have offered better opportunities for arable farming. Unfortunately, palynological data concerning these periods are virtually absent so that any environmental reconstruction for these periods on the basis of such data is impossible.

Shortly after deposition, the clay will have been saline. Desalination, however, may occur after the inundations ceased. In the Dutch Grevelingen, just south of Voorne-Putten, desalination took place after damming up of the area by dikes. Already within one year, desalination occurred locally, and after eight years, large parts of the area were desalinated (Buth 1984: 969). In the sixteenth century, desalination of salt marshes in the British coastal area of Lincolnshire took about ten years (Thirsk 1965: 14).

The sea maintained its influence in the coastal area near Rockanje. In this salt marsh environment, barley could have been cultivated, but emmer could not. Of oil crops, gold of pleasure is the one most suited for cultivation in salt marshes, while linseed may also be cultivated successfully.

Some caution is needed in extrapolating the present agricultural criteria to the past. It is possible that less than optimal soils were well-suited to former requirements. It would be safest to provide botanical evidence for the possible local cultivation of crops. Firstly, clues may be provided by the remains of the crops themselves, secondly, the weeds may also be indicative of the conditions on the arable soils.

Cereals and the remaining crops are treated separately here in the discussion of crop plants, in view of the different interpretations that may be drawn from these crops.

6.4.2 EVIDENCE FOR LOCAL CULTIVATION PROVIDED BY THE CEREAL REMAINS

On all the Iron Age sites in the present study, wheat has been demonstrated, while it occurs much less frequent in the native Roman settlements. Barley plays a major role on nearly all the sites, with Spijkenisse 17-30 as an important

exception. Chaff-remains always considerably outnumber the amount of grain kernels. This is not surprising, since kernels provide the edible product and chaff is the discarded waste. A review of the interpretation of the occurrence of grain kernels and chaff through the development of palaeo-ethnobotany is appropriate to estimate the occurrence of grain and chaff on its merits.

In early publications, the possibility of import of a vegetable crop into a (prehistoric) settlement site was not considered. Grain species found on a site were presumed to have been cultivated by its inhabitants. Later, the occurrence of grains without chaff was seen as evidence that the grain might not have been grown locally (cf. Knörzer 1970 for barley). The chaff was seen as providing proof of local production. The occurrence of *Cerealia* pollen has also often been interpreted as proof of local cultivation (e.g. Grohne 1957b: 242; Behre 1983: 184; 2.4.1).

Körber-Grohne (1967) made a considerable contribution to the development of studies in the coastal area in her investigations of the Feddersen Wierde in the northern German salt marsh area. She did not accept the list of crop plants as given, but she explored the possibility of cultivating them in an extant, similar environment. In doing so, she could demonstrate that barley, gold of pleasure and Celtic bean were indeed the crops most suited for cultivation in a salt marsh environment, and that it was not coincidence that they were the predominant species in her subfossil material.

Another landmark in the discussion on the cultivation of crop plants was reached by Hillman (1981) and G. Jones (1984). By analysing the products and by-products in recent processing of cereal crops in Turkey, Hillman could construct flow-diagrams of the different steps involved in crop-processing of glume wheats and of free-threshing cereals. G. Jones (1984) presented a flow-diagram for processing of free-threshing cereals in Greece. As Hillman noticed, there are few non-mechanized possibilities in processing a crop, both in the overall sequence as well as in operations. Thus, the use of ethnographic models for the interpretation of prehistoric finds seems justified.

On the basis of these diagrams, Hillman was able to draw valuable conclusions, also strongly influencing the interpretation of prehistoric finds of remains of cereals, especially those of glume wheats (see also Bakels 1985: 195).

The most important conclusion regarding prehistoric economies is the fact that in humid areas emmer grains are stored and transported when they are still enclosed by their glumes. The separation of grains and glumes (chaff) occurs at the final processing, which takes place meal-wise, just prior to consumption. One of the main advantages of this method of storage is that the grains are less susceptible to rotting.

The extrapolation of these recent observations to the pre-

historic situation is supported by the find of grains with glumes of emmer in pre- and early historic granaries and silos, in the Netherlands for instance in native Roman Schagen-Muggenburg (Pals/ Troostheide cited in Pals *et al.* 1989) and in Iron Age Colmschate (Buurman 1986).

At first sight the grains found in silos in Colmschate appeared to be threshed completely as the glumes were absent. However, Buurman did find pairs of grains still attached to each other with their ventral sides, as in their position in glumes. By artificially carbonizing complete (recent) ears, including all chaff, she found that under certain circumstances the chaff burnt to ashes and only the naked grains remained. Thus, it is risky to interpret a carbonized amount of naked grains of glume wheats as being completely threshed².

Furthermore, Sigaut (1988) reasoned that the Portuguese word *Espigueiro* and the German word *Speicher* both derived from the medieval latin *spicarium*, which would mean "granary for spikes". According to him, this suggests a wide distribution of grain storage in ears in Europe in early and medieval times. This would also apply to the Dutch equivalent *spieker*. Varro also described storage of hulled wheat (*i.e.* spelt) in its chaff (cf. Hooper 1936: 299). Another hint for the storage of glume wheats in spikelets is offered by Plinius, who described the sowing of spelt and emmer in the chaff (cf. Van der Poel 1960-61), which also requires such storage.

The important conclusion from this observation is that the occurrence of chaff of glume wheats on a particular site does not necessarily imply local cultivation, provided that Hillman's model is valid for the prehistoric situation. According to his model, the only remains that do exclusively occur on production sites and are discarded during the first stages of crop processing, are cereal stems and larger stem fragments (see Hillman 1984). Theoretically, these would provide the unambiguous proof of local production. It seems illogical to assume that complete sheaves were traded in prehistoric times, when transport of large bulks will have provided logistic problems.

It is highly remarkable, however, that stems of cereals are very seldom found in archaeological material. Körber-Grohne (1967: 136) for instance stated that although the dwelling mound layers in Feddersen Wierde were thoroughly searched for cereal straw, only a few carbonized culm fragments could be found. Uncarbonized straw could not be attested at all, despite the excellent preservation of other waterlogged material. M. Jones (1985: 117) and Van der Veen (1991: 353) also observed that straw debris tends to occur in very low quantities in Iron Age assemblages from Britain. Similar observations are very common in palaeo-ethnobotanical literature.

In view of the frequent occurrence of reed stems (*Phragmites australis*) in the sites on Vorne-Putten, it is question-

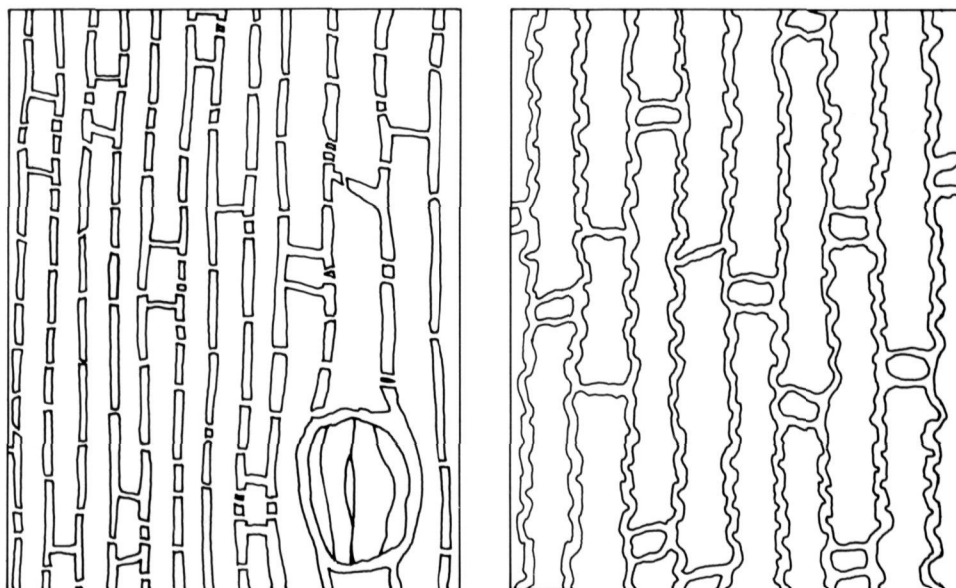


Fig. 60 Epidermis cell pattern of reed and cereals (ca. 600x).

able whether there is cereal straw present among these stems. According to Körber-Grohne (1967: 136) reed stems can be distinguished from those cereal stems by the presence of an adventive bud above the culm nodes, which is absent in cereals. To assure that this feature also applies to prehistoric cereals, I tried to find a second distinguishing characteristic. It appeared that the epidermis cell pattern (see fig. 60) strongly differed between recent specimens of these taxa (see also Brinkkemper 1991). According to this criterion, the subfossil stems with adventive buds did indeed belong to reed.

In the macroremains from Rockanje II and Spijkenisse 17-30, some grass stems were found among many stems belonging to reed, that did lack the adventive bud which characterizes *Phragmites*. The epidermes of these stems, however, appeared to have two short cells alternating with one long cell, which does neither occur in cereals nor in reed. The pattern is that of *Molinia* described by Grosse-Brauckmann (1972). Since it cannot be excluded that other grasses also have this epidermis pattern, the stems have been listed as *Molinia*-type. In conclusion, even in the few cases that the absence of the adventive bud points to cereal stems being involved, it does not necessarily have to be cereal.

Cereal stems have not been found in the present study, and the few finds reported elsewhere might belong to other grasses than cereals. Thus, the presence of cereal stems seems a most unreliable criterion to demonstrate local grain production. Most probably, the straw was not harvested at all (see 6.4.3).

For the extrapolation of Hillman's data onto the pre- and protohistoric situation, still another point must be stressed

here. Botanical investigations have demonstrated that hulled cereals were not always transported in their chaff, at least not in the Roman world. This is clearly illustrated by the data obtained from a Roman grain ship found near Woerden (the Netherlands) by Pals and Hakbijl (*in press*). The cargo consisted of emmer wheat and the destination was most probably the nearby Roman military fort (*castellum Laurium*). The amount of chaff is only a fraction of a percent of the amount of grains. All the remains are waterlogged, so carbonization cannot have caused the disappearance of the glumes. It is thought that transport occurred in the form of a completely processed crop, which saves up to 20% of the space needed by emmer in glumes (see 6.6.3.2).

The contents of a so-called *horreum* in the Roman *castellum Praetorium Agrippinae* near Valkenburg with bread (club-)wheat and hulled barley (Pals *et al.* 1989) and of a granary with the glume wheat spelt in the Roman *villa* near Voerendaal (Willems/ Kooistra 1988) both revealed almost pure grain with very few chaff remains. This once more is evidence of storage of completely threshed grain in a Roman military context, provided that the chaff did not disappear during carbonization. However, the finding of emmer, spelt and barley in their chaff in the Roman *castellum* of Valkenburg by Van Zeist (1970) illustrates that this storage method was also in use in *castella*.

Hillman's ethnographic model is not the only one that can be applied to trace production and import of cereals. M. Jones (1985) used archaeobotanical data to derive statements on production and "consumption". Since consumption also occurs on a grain producing site, I prefer to use the expression "import" instead of "consumption".

Jones studied the botanical macroremains from four sites along the Thames, where the glume wheats emmer and spelt also appeared to be the predominating cereals. Two sites were located on the drier second gravel terrace, on free-draining, reasonably fertile land well suited to cereal production. Two other sites were situated on the first gravel terrace, in a wet environment in which open pasture seems a key element. On the basis of the numbers of macroremains, Jones constructed triangular diagrams, in which he plotted the percentages of grain, chaff and weed seeds for each sample on the three axes. It appeared that samples with high percentages of grain all had come from the drier locations on the second terrace. On these sites, the percentage of grain very rarely dropped below 30%. In the samples from the sites on the first terrace, chaff and/or weed seeds attained high percentages, while grain remained below 50% on one site and below 15% on the other. Jones explained these differences as follows (Jones 1985: 120):

"The most likely place for this unlikely event [the deposition of grain as debris] to occur is at its place of production. With further processing and transportation, the perceived unit value of the crop accrues, while its quantity at any single point lessens. The chance of the prime product itself being discarded into a fire consequently drops. A non-producer site receiving the harvest product through exchange is likely to allow only the waste material from any final processing to be discarded into the settlement fires".

Interestingly, clusters of pits (for grain storage?) occur on the sites on the second gravel terrace and not in those on the first, which instead show larger numbers of ditched enclosures (for control of animals?). Robinson (1981) demonstrated that beetle remains (Coleoptera) found on a site on the floodplain provided "overwhelming evidence for the importance of pasture". This floodplain is still closer to the river bed than the first terrace. Apparently, the inhabitants of one group of sites are mainly arable farmers and those from another group of sites pastoralists.

When Jones' model is confronted with the ethnographic data provided by Hillman, some discrepancies are significant. In Hillman's model, grain kernels occur as waste on "import" sites during several stages of crop processing. This contradicts with Jones' assumption that these kernels are mainly to be found on production sites. Furthermore, in Jones' model, weed seeds play a major role on consumption sites, whereas in Hillman's flow diagram they are also important on the production side. As far as the first point is concerned, it can be remarked that Hillman's diagram does not provide quantitative information. The absolute numbers of grains discarded on both sides of the transportation phase may differ considerably, which theoretically may result in high percentages of discarded grain on production sites. A weak point in Jones' model, in my opinion, is the lumping together of all the non-cereal remains as "weed seeds". As a result, the percentages of grains (and chaff) are

reduced by species that are not connected with the cultivation or import of crops.

In conclusion, Hillman's crop processing diagram for glume wheats cannot be applied to demonstrate production of glume wheats in every case where the straw was not harvested. It is also regrettable that this diagram does not provide quantitative information. Jones' model does provide such quantitative data, but the subordinate role of weed seeds on production sites is in strong contrast to Hillman's observations, and the indiscriminate use of all weed species, irrespective of their ecology, is debatable. On sites such as those described by Jones, where only carbonized material has survived, the use of all the weeds may not be of too great an influence. On wetland sites, however, weed species which are not arable weeds are much more important. This can be explained by the fact that their chances of carbonization are relatively low. Furthermore, Jones' production and "consumption" sites are in fact both ends of a continuum, from surplus production through self-support and import of part of the crops needed to complete import. This is also put forward by Van der Veen (1987), who constructed a triangular diagram based on macroremains of the British Iron Age settlement at Thorpe Thewles. This diagram is intermediate between Jones' two types of diagrams, possibly indicative of a self-supporting cereal production. Van der Veen (1991: 357) suggested four broad categories: subsistence production, production for a surplus, small consumer sites and large urban complexes, which also are arbitrary levels in a continuum.

Both Hillman's and M. Jones' models discussed above apply to glume wheat species. This is only one of the two major cereal crops found on Voorne-Putten, the other one being hulled barley. Notably, G. Jones (1984) and Hillman (1981, 1984) conceive hulled barley as a free-threshing cereal. In free-threshing cereals, storage does not take place before grains and rachis internodes have been separated, which can simply be achieved by threshing and winnowing. In Hillman's (1981) model for free-threshing cereals, the paleas and lemmas ("hulls" according to G. Jones *pers. comm.*) still have to be removed. This removal is mostly done with loosely-set rotary-querns or by pounding. However, in contrast to the situation in glume wheats in humid climates, storage takes place after separation of the rachis internodes (and straw) from the grains plus hulls by flailing and winnowing. According to this model for free-threshing cereals, the occurrence of rachis internodes of barley is restricted to production sites, just as those of the free-threshing bread wheat. This concurs with an important observation put forward by Behre (1983). In his comparison of the German medieval sites of Elisenhof (rural) and Haithabu (trade centre), he found that the ratio of rachis internodes to grains in hulled barley was 149.3% in Elisenhof and 0.24% in Haithabu. He attributed this difference to

local production in Elisenhof and import from farms outside in Haithabu. Knörzer (1970) found 98,000 grains and 61 internodes of barley in the Roman *castellum Novaesium*, which he interpreted as evidence for import too. It seems most likely that this applies to the prehistoric situation as well. The relatively simple methods of flailing and winnowing considerably reduced the volume and weight of any traded amount of hulled barley.

The remaining cereal crop found on Voorne-Putten, *Panicum* is stored in its chaff which is, however, easily lost after carbonization.

6.4.3 HARVESTING METHODS

Strictly following Hillman's models, the virtual absence of cereal straw in the samples studied seems to imply that all the archaeological sites investigated on Voorne-Putten are grain importing sites. However, the presence of straw fragments requires that part of the stems are harvested together with the grain ears. Such a harvesting method is obligatory in Hillman's model.

In this respect, the height at which the plant is cut is of relevance. This height can be reconstructed by means of the heights of cropweeds harvested together with the crop. In the present study, nearly all stenoecious crop weeds (with a narrow ecological amplitude) are tall species. Stenoecious summercrop weeds that remain close to the ground do exist. In the present study, only one specimen of these low weeds has been found, viz. one single seed of *Anagallis arvensis*. Besides, this seed occurred in a sample from Geervliet 17-55 in which *Camelina sativa* is a major component. Körber-Grohne (1967) found stems and roots of *Camelina* in the refuse layers in Feddersen Wierde (northern Germany), and so demonstrated convincingly that this crop was harvested by uprooting. Thus, the single *Anagallis* seed is likely to have come from a plant in a *Camelina* crop, and not in a cereal crop. Similarly, the occurrence of low-growing weeds on other sites, which has been interpreted as evidence for harvesting close to the ground (e.g. Körber-Grohne 1967; Knörzer 1971b) might (partly) have belonged to crops other than cereals. Behre (1983) for instance found much larger amounts of low-growing weeds in samples predominated by *Linum* than in remains of cereal crops. Willerding (1971) concluded that in the case of cereals, ears were harvested during the Neolithic, Bronze- and Iron Age, since the crop weeds mentioned in a range of publications are practically always tall species. Kroll (1987) did find low growing weed species in preserved Iron Age arable field soils on the island of Sylt (e.g. *Rumex acetosella* and *Spergula arvensis*). On the site connected with these fields, however, almost exclusively tall species were found, which is a clear example of the effect of the harvesting method on the selection of seeds that find their way to a settlement site.

For the harvesting method used on Voorne-Putten, an

observation made by Reynolds (1981a) is of relevance. He indicated that in harvesting ears by hand-picking, the transitions from stem to internodes are not represented in the harvested material, whereas they are after harvesting with sickles, irrespective whether low or high on the straw. In the material from Voorne-Putten, only one such transition has been found in a carbonized state in Nieuwenhoorn (Roman Period). Uncarbonized transitions were not found, notwithstanding the fact that uncarbonized chaff is as common as carbonized. The single transition found is much less than might be expected if harvesting occurred with sickles. From this it can be concluded that harvesting by means of hand-picking was practised. Even today this is a widespread method of harvesting in poorly mechanized agricultural systems.

Harvesting by picking of ears may also account for the relatively low amount of crop weeds, which does not only occur on the present sites, but has also been observed by Dennell (1974) and Knörzer (1971a). Varro described this practice to save labour (cf. Hooper 1936: 287). This also implies that cereal straw cannot be expected to occur abundantly on the sites (see 6.4.2). In consequence, the absence of straw does not provide a reliable clue to local production or import of the cereals concerned.

Most probably the straw remained on the fields. One possibility is that it was ploughed into the soil (cf. Enklaar 1837), which would improve the texture, but the decomposition would withdraw nitrogen. This could have been overcome by burning the straw on the fields before ploughing. The use of an ard for ploughing might not have been sufficient to plough the straw into the soil. However, from the Middle Iron Age onwards, a mouldboard plough appears to have been used throughout the entire coastal region (Van Heeringen 1992: 319). With this implement the straw probably could be ploughed under. An alternative possibility is that the straw was fed to cattle or other domesticates directly on the arable fields (cf. Knörzer 1971a). Reynolds (1981b, 1987b) stated that the straw of prehistoric cereals is quite palatable to livestock. Spahr van der Hoek (1952) also mentioned the use of straw to feed cattle during the 18th century. This practice is still in use. Whether or not prehistoric straw could serve as fodder for cattle when still on the fields must remain uncertain. However, it would be a very efficient way of dunging.

A last possibility is that the straw was harvested separately from the ears, as is indirectly mentioned by the Roman author Varro. According to him, the straw should be cut within 30 days after the ears were cut (cf. Skydsgaard 1968: 53). In areas where reed was less abundant, straw could have been used for thatching. Slicher van Bath (1987: 207) also described a separate harvesting of the straw during medieval times, to be used for thatching. Straw could also have been used as winter fodder or as litter. However, straw

was not used on the sites dealt with here, as it would have been found among the botanical macroremains.

6.4.4 THE EVIDENCE FOR LOCAL CULTIVATION PROVIDED BY NON-CEREAL CROP REMAINS

In the present study, the most important crops next to cereals are linseed and gold of pleasure. Ethnographic studies of the processing of these crops for seeds are unknown to me. However, anyone separating seeds and chaff of *Linum* or *Camelina* for a reference collection will experience the great ease of this task. These crops are undoubtedly comparable to free-threshing, naked cereals.

Dewilde (1984) mentions that the oldest and most primitive method of freeing flax seeds from their capsules will have been by hitting well-dried and ripe seed capsules against a wall or a floor. In analogy to Hillman's and G. Jones' models (see above), it can be expected that bulk storage and transport occur in the stage of seeds. Therkorn *et al.* (1984: 32) found ca. 200 *Linum* seeds and no capsules or stems in the Iron Age site of Assendelft-Q. They concluded that linseed was imported occasionally for consumption. Only *Linum* is cultivated locally are capsule segments to be expected. Behre (1983) even goes one step further when he states that if linseed is traded, this would be as oil pressed from the seeds to facilitate transport.

In the case of *Camelina sativa* it may also be expected that local cultivation results in the presence of silicles on the site. *Camelina* has been found abundantly on site Q of the Assendelver Polders. In view of the numerous threshing remains, Therkorn *et al.* (1984) conclude that this crop was produced by the inhabitants of the site themselves. This site is situated on a (drained) raised bog. Apparently, *Camelina* could be grown in the surroundings of the site, whereas *Linum* could not.

The suggestion that *Camelina* may have been cultivated on peaty soils around Assendelft is of relevance for the Early and Middle Iron Age situation on Voorne-Putten. This crop could probably have been grown near the sites, although the actual cultivation of this crop does not confirm this suggestion. Agricultural experiments on peaty soils could demonstrate the reality of growing *Camelina* there.

Next to cereals and crops cultivated for their oil-rich seeds, leguminous crops form a third category. For all leguminous crops it is extremely difficult to assess their importance for the economy of a site as uncarbonized leguminous seeds are highly perishable and thus very rare (cf. Willerding 1971). Moreover, the chances of their seeds becoming carbonized are much smaller than in hulled cereals. Körber-Grohne and Kroll (1984) stated that even in the German coastal settlements where great amounts of waterlogged straw of Celtic beans occur, the carbonized seeds of this species are still rare. Behre (1983) concluded that *Vicia faba* was not cultivated locally by the inhabitants of Haithabu's

trade centre, seeing the absence of straw, roots and pods. The presence of straw, roots and pods is considered to point towards local production. However, the fact that no bean straw was found in the present study must not immediately be interpreted in the same sense. According to Van Zeist (1970: 164), pods or stems of Celtic bean have never been encountered in Dutch sites. It could be that bean straw is highly perishable. According to Behre (*pers. comm.*), however, the straw of Celtic bean is as resistant to decay as reed stems. The fact that bean straw was found in several German dwelling mounds may be due to deliberate collecting of this straw to be used as material to raise the level of the mound. On Voorne-Putten, the settlements were not raised as much as in the northern German salt marsh area so the need for heightening material may have been considerably lower. This may explain why bean straw was not transported to the sites. The threshing, by flailing or suchlike after drying of the plants, may very well have taken place on the fields, after which the seeds could simply be collected. Cattle may have been fed the nutritious bean straw directly on the arable fields.

6.5 Implications of the botanical investigations on the reconstruction of agricultural economies of the sites.

To be able to include both arable farming and stock breeding in one interpretative model, it is appropriate to review the results that were obtained through the analyses of botanical remains (pollen, wood and macroremains) from the sites on Voorne-Putten. This review is presented in the following paragraphs, table 33 provides a summary of the crop plants found in the various sites.

6.5.1 THE EARLY IRON AGE

Three Early Iron Age sites have yielded data about botanical macroremains. Rotterdam-Hartelkanaal 10-69 produced cereal imprints in pottery which were all identified as barley (*Hordeum vulgare*). Not a single crop plant, nor a crop weed could be attested in the refuse layers of this site. All plant remains belonged to species of reed vegetations, which presumably grew close to the site. Van Trierum (*in press*) furthermore observed that only a very thin refuse layer, with little domestic waste like sherds, had developed on this site. The poor durability of the alder wood used for building this house would not allow a long inhabitation.

In Spijkenisse 17-30, a remarkable set of crops was found. The cluster analysis based on these crop plants also showed this site to be different from all others (see 4.7.3). *Brassica rapa* appeared to be numerous, but it cannot be ascertained whether this was a true crop plant or whether the seeds were gathered from wild plants. *Panicum miliaceum*, millet, was present exclusively on this site. Emmer (*Triticum dicoccum*) was also regularly found. Barley (*Hordeum vulgare*), gold of

Table 33. Frequency of crop plants on Voorne-Putten. * = impressions present.

site period	RH.10-69 E.I.A.	Sp.17-30 E.I.A.	Sp.17-35 E.I.A.	Sp.17-35 M.I.A.	Sp.17-34 M.I.A.	Gv.17-55 M.I.A.	Ab.17-22 L.I.A.	Zl.16-15 L.I.A.	Zl.17-27 L.I.A.	Ro.08-52 L.I.A.	Nh.09-89 R.P.	Rock. R.P.
<i>Hordeum vulgare</i>	—*	—	2/5	1/3	13/19	3/3	—	1/1	2/2	7/12	10/27	12/23
<i>Triticum dicoccum</i>	—	3/9	—	1/3	13/19	3/3	1/1	1/1	2/2	6/12	7/27	2/23
<i>Panicum miliaceum</i>	—	1/9	—	—	—	—	—	—	—	—	—	—
<i>Linum usitatissimum</i>	—	—	1/5	1/3	9/19	3/3	1/1	1/1	2/2	6/12	3/27	—
<i>Camelina sativa</i>	—	—	1/5	1/3	1/19	3/3*	1/1	—	2/2	3/12	1/27	—
<i>Brassica rapa</i>	—	8/9	—	2/3	4/19	1/3	1/1	—	2/2	—	—	—
<i>Vicia faba</i>	—	—	—	—	—	—	—	—	—	—	4/27	—

pleasure (*Camelina sativa*) and linseed (*Linum usitatissimum*) are conspicuous by their absence. Stenoecious crop weeds are completely absent on this site. Moreover, cereal chaff is scarcely represented on this site (see 4.6.3).

The Early Iron Age samples from Spijkenisse 17-35 did reveal low amounts of barley, linseed and gold of pleasure. Wheats are absent in the Early Iron Age samples from this site. The sparse presence of barley internodes and *Linum* capsules may demonstrate the cultivation of these crops by the inhabitants of Spijkenisse 17-35. This site is the only Early Iron Age site where stenoecious crop weeds could be demonstrated, despite the fact that in the case of Spijkenisse 17-30 more samples were analysed which also yielded more crop plant remains, even if *Brassica rapa* is excluded.

Palynological data could only be obtained from Spijkenisse 17-30. Peat apparently grew here through to the Middle Iron Age. Despite the fact that the pollen section was situated 6 m outside the wall of the farm, not one single pollen grain of a crop plant could be found. The threshing of cereals in quantity normally produces a considerable contribution of Cerealia-type pollen to the local pollen rain. Particularly grains of emmer wheat can be identified with relatively great certainty as belonging to Cerealia-type. This does not apply to barley, since the *Hordeum*-type includes a whole range of wild, especially coastal, grasses. None the less, the emmer wheat found in the macroremains of Spijkenisse 17-30 could not be attested in the pollen spectra, which according to the ^{14}C dates are synchronous with the habitation. One possible explanation may be that no peat formation occurred during the habitation. This would not be surprising, seeing the close distance of the pollen section to the house wall. Nevertheless, a standstill of one or two decades would produce an oxidation horizon in the peat. This could not be observed in the section. Furthermore, the regularity of the cumulative pollen influx curve and the good fit of the ^{14}C dates to this curve also are in sharp contrast with a standstill in peat formation. If it is indeed assumed that the peat formation continued during habitation of the site, it must be concluded that large scale threshing of cereals in the open air cannot have taken place in Spijkenisse 17-30.

At first sight, this observation seems to be in sharp contrast to the occurrence of emmer glume bases, which is the chaff discarded during crop processing. However, the previously discussed ethnographical investigation by Hillman (see 6.4.2) demonstrated that chaff of glume wheats also may occur on sites where import of these glume wheats occurred. The final processing of this crop also results in the separation of pollen grains. Their absence in Spijkenisse 17-30 can only be explained by small-scale, indoor processing of emmer.

To further explore the cultivation of emmer, the possible location of the arable fields must be reconstructed.

The palynological investigation revealed the presence of levees along the Meuse. During the Early and Middle Iron Age, the primary forest trees showed a considerable decline. These observations are explained by human intervention in the natural forest to produce arable fields. The absence of wintercrop weeds on the sites studied indicates that crops were most probably grown on these levees. The regular flooding of these levees in winter will have prevented the cultivation of wintercrops.

Groenman-van Waateringe (1979) stated that along coasts and riversides, where annual sedimentation of fertile soil took place, permanent cultivation without manuring or fallow was probably possible. Heresbach, describing the 16th century situation, also stated that regions that are regularly flooded by rivers may be cultivated permanently, without a fallow period (cf. Dreitzel 1970).

Whether the levees were farmed by the inhabitants of the sites near Spijkenisse themselves cannot be concluded from the botanical macroremains. If the inhabitants of Spijkenisse 17-30 had grown their own crops there, they would also have processed it. The first steps in crop processing might have occurred directly on the fields, after which transport (over water?) of semi-cleaned spikelets to the site may have taken place. Thus, the absence of Cerealia-pollen in the pollen section next to the farm does not necessarily attest that the crop was obtained from the inhabitants of other farms, viz. those on the levees.

Still, the location of arable fields at three to four km distance from the site has considerable implications. Firstly,

protection of the crops becomes problematic. Although the glume wheats are relatively resistant to predation by birds, deer species also occurred in the area (see *ch.* 5). With unprotected fields, they may have caused great damage to the crops. Besides, human beings might also have been interested in the crops.

Secondly, the excavated Iron Age farms have never revealed evidence of granaries accompanying the buildings. Storage pits can be excluded in the wet Holocene part of the Netherlands. This concurs with the fact that silos are restricted to the Pleistocene sand and löss soils (Roymans 1985). Thus, storage of crops can only have taken place inside the house. In the case of Spijkenisse 17-30, such a storage place might have existed in the central part of the building between the byre and the living quarters (Van Trierum *in press*). Kroll (1987: 53) described a 10 cm thick layer of carbonized grain in the byre area of a burnt down farmstead on Sylt (northern Germany), dating to the 3rd century AD. This indicates that the crop was stored in the house, most probably on a loft. Another observation of grain storage inside a house has been provided by one burnt-down farm on Feddersen Wierde, which also dates from the Roman Period (Haarnagel 1979: 119). However, the large scale excavations near Oss on the Pleistocene sandy soils along the Meuse did nearly always reveal some granaries accompanying Iron Age farms (K. Schinkel *pers. comm.*). Iron Age settlements on mineral soils in the coastal area often did reveal granaries as well (Van Heeringen 1992). These arguments seem to plead against a large-scale cereal production by the Early Iron Age inhabitants of Voorne-Putten.

However, Chisholm (1968: 48) observed that

"the average distance to the cultivated land is commonly of the order of one kilometre or more and very frequently rises to three or four".

It is impossible to judge this observation in view of the objections mentioned above.

The alternative to the model of cereal cultivation on fields at a relatively great distance is the following situation. The levees along the Meuse might also have been inhabited. The people living there grew crops on these levees and had a considerable over-production. This surplus is exchanged with the peat-dwellers, who specialized in rearing livestock. This model would predict the absence of relatively large byres with stalls in the farms on the levees, while the occurrence of granaries would be expected.

Unfortunately, the levees along the Meuse have been eroded and therefore these predictions cannot be tested on Voorne-Putten. However, of significance is the fact that on IJsselmonde and the Hoekse Waard, just upstream of Voorne-Putten, Iron Age traces were found on levees along smaller tributaries of the Meuse, which have not been

eroded (cf. Van Trierum *in press*). There, the model could be tested.

This model of exchange was introduced by Brandt and Van Gijn (1986) to explain the situation in the Assendelver Polders during the Iron Age. This area is highly comparable to Voorne-Putten as far as the Iron Age habitation is concerned. Some farmsteads were located in a peaty environment (e.g. site Q). In this area also some sites on relatively small levees accompanying creeks could be excavated. Indeed, most Iron Age and Roman farms found on these levees did not show traces of stalls (Brandt/Van Gijn 1986: 69).

The exchange-model was incorporated in a model explaining the sequence of events in the colonization of the Assendelver Polders by Brandt *et al.* (1984). The first step is thought to be occasional and seasonal visits of the area, mainly for reconnaissance trips and subsequently to provide a grazing territory for cattle. During these seasonal visits, the agricultural potential of the formerly uninhabited area could be assessed.

The following phase according to Brandt *et al.* is the foundation of permanent inhabitation, which still completely specialized in cattle breeding. For the supply of crop plants, an exchange with relatives living in drier areas is suggested. The last phase in this model is the return of a predominantly self-supporting, autarkic economy, with the cultivation of crop plants by the descendants of the colonists. Brandt *et al.* were of the opinion that desiccation of the peat owing to a transgression could trigger the above-mentioned sequence. Recovery of the peat growth may cause the termination of the occupation. The relation between natural conditions and habitation has been presented as a cyclic sequence by Brandt *et al.* (see *fig. 61*). It can be asked how much time is required for the total sequence. Brandt *et al.* do not indicate any time span thought to be involved in their model. They do state, however, (1984: 4) that the peaty area was drained adequately for c. 75 years during the Early Iron Age.

The pattern of this colonization in three steps compared to the data provided by Early Iron Age sites on Voorne-Putten shows many remarkable similarities. Voorne-Putten was uninhabited during the later part of the Bronze Age. The Early Iron Age inhabitants thus colonized the area. The

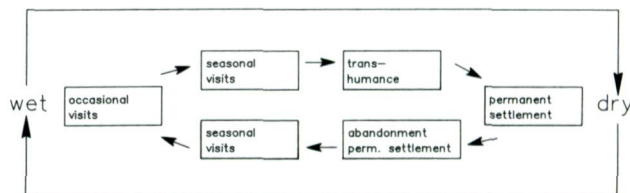


Fig. 61 Cyclical model for colonization of a peaty area (according to Brandt *et al.* 1984).

site of Rotterdam-Hartelkanaal 10-69 seems to have been inhabited relatively shortly, the construction cannot have stood for more than a decade considering the poor durability of the alder wood used. This site may very well be an equivalent of the pioneering transhumant stage. The absence of crop plants and their weeds in the thin refuse layer of Rotterdam-Hartelkanaal would fit in well with this assumption, but the quantity and quality of the samples is too low for well-founded statements.

The second -exchange- stage could be represented by Spijkenisse 17-30. The farm is made of a better quality wood, the uprights being mainly constructed of elm and sycamore. The deviating spectrum of crop plants, the absence of stenoecious crop weeds (see table 30) and the relatively high importance of grassland plants (see table 28 and 30) all may indicate a specialization in stock-raising and the import of crops. However, as stated above, the botanical data cannot be used as definite evidence against the cultivation of crops by the inhabitants themselves at a relatively great distance from the site. The absence of granaries near the site, the absence of Cerealia-type pollen in the peat next to the site and the difficulty in protecting the crops sufficiently in fields at several kilometres distance are all in favour of the exchange model for Spijkenisse 17-30.

Spijkenisse 17-35 is the only excavated Iron Age site on Voorne-Putten where habitation during two phases could be demonstrated, viz. Early and Middle Iron Age. The spectrum of crop plants differs considerably from that of Spijkenisse 17-30 and does agree more closely with the crops found on the later Iron Age sites. Furthermore, the presence of several stenoecious summer crop weeds may indicate a greater role for arable farming in comparison to Spijkenisse

17-30. The presence of internodes of the free-threshing hulled barley and the processing by-products of *Linum* also give an indication for the cultivation of these crops by the inhabitants themselves. None the less, Spijkenisse 17-35 is also located at a distance of 3-4 km from the levees along the Meuse. No granaries were discovered at the site either, so the objections against crop farming for Spijkenisse 17-30 also apply to this site. However, the fact that barley, the main cereal in the Early Iron Age samples of Spijkenisse 17-35, could probably have been cultivated on peat near the settlement, is of great relevance. Local cultivation of barley on peat may have made the inhabitants of Spijkenisse 17-35 more independent in their food supply.

According to Van Trierum (*pers. comm.*), the pottery of the three Early Iron Age sites does not provide any clues on the time sequence of these three sites. ^{14}C dates obtained from wood of the three sites do not reveal a time sequence either (see fig. 62), mainly as a result of the huge wiggles in this part of the calibration curve (cf. Baillie/ Pilcher 1983).

6.5.2 THE MIDDLE IRON AGE

Although the Middle Iron Age is the phase of the Iron Age about which most sites are known on Voorne-Putten, Spijkenisse 10-28, 17-34 and 18-50 are the only sites that yielded partial house plans from this phase. From these, only Spijkenisse 17-34 has been investigated for botanical macroremains. Both other sites were excavated at a time when it was not common practice to sample for botanical macroremains. In Spijkenisse 17-35, one single row of posts was found. Geervliet 17-55, the third Middle Iron Age site studied has not been excavated (see 4.1.1).

In Spijkenisse 17-34, barley, emmer and linseed occur frequently, while one gold of pleasure seed and some rape seeds were recorded. This spectrum of crop plants and the occurrence of some stenoecious summercrop weeds resemble the data obtained from the Early Iron Age site of Spijkenisse 17-35. The numerous rachis internodes of barley and the (few) capsule segments from linseed point to the cultivation of these crops by the inhabitants of Spijkenisse 17-34. The occurrence of numerous carbonized manna-grass remains in Spijkenisse indicates the gathering of this species (see 4.5.5). Apparently, the demand for carbohydrates could not be satisfied by crop plants in one or more years.

The Middle Iron Age samples from Spijkenisse 17-35 revealed barley, emmer, linseed and gold of pleasure. The presence of rachis internodes of barley and of capsules resp. silicles of linseed and gold of pleasure demonstrate that these crops were grown by the inhabitants themselves. For emmer, this cannot be ascertained in view of the absence of straw.

The macroremains from Geervliet 17-55 show the greatest share of crop plant remains of all sites studied. Especially gold of pleasure and linseed remains are abundant. The

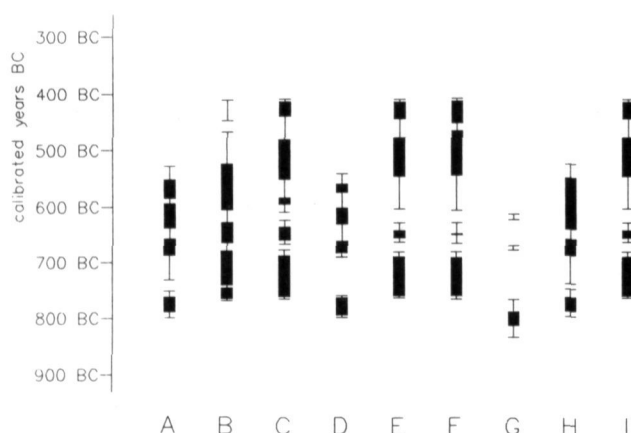


Fig. 62 Calibration of ^{14}C dates obtained from wood of Early Iron Age settlements (A-C = Rotterdam-Hartelkanaal; D-F = Spijkenisse 17-30; G-I = Spijkenisse 17-35). Black = 1σ interval; line = 2σ interval.

ubiquity of threshing waste (silicles and capsule segments) again may be conceived as evidence for local production of these crops. Unfortunately, none of these sites have yielded pollen data from deposits close to the site. The diagram from Spijkenisse 17-30 did show peat formation during the Middle Iron Age, but no pollen of crop plants could be recognized. This cannot be taken as firm evidence that no crops were grown near the sites. The fact that crops with anemophilous (wind dispersed) pollen do not occur among the Iron Age crops may explain their absence.

The presence of numerous crop-processing by-products is a strong indication for the permanence of the Middle Iron Age inhabitation, since cultivation of crops in a non-permanent settlement is highly improbable.

According to Van Trierum (1986: 69), there is a gap of one century in the habitation on Voorne-Putten during the Early and the Middle Iron Age, caused by renewed peat growth in the period in between. ^{14}C dates support this statement. The model presented by Brandt *et al.* (see fig. 61) predicts that colonization would start again with transhumance visits, followed by specialized cattle breeding before a self-supporting economy can develop again.

The Middle Iron Age counterparts of the Early Iron Age sites of Rotterdam-Hartelkanaal and Spijkenisse 17-30, with little habitational refuse and the absence of specific crop weeds, apparently are not present on Voorne-Putten. This may simply be attributed to the small number of sites investigated. If the absence of sites belonging to the first two phases of settling, however, still holds after investigation of more Middle Iron Age sites, it must be assumed that the potential of the area, discovered during the Early Iron Age, was still known during the Middle Iron Age, even after a habitation gap of one century.

6.5.3 THE LATE IRON AGE

According to Van Trierum (1986: 69), the clear gap that divides the habitation of the Early and Middle Iron Ages is not present between the Middle and Late Iron Ages. The Dunkirk I deposits that separate both phases is not an absolute time boundary, as has clearly been demonstrated by the Late Iron Age site near Rockanje, which lies stratigraphically below Dunkirk I sediments, while the Late Iron Age sites near the Bernisse lie on top of these deposits. Thus, the inhabitants probably were not forced to leave Voorne-Putten entirely, since there were always areas that were inhabitable notwithstanding the marine influence.

Of the known Late Iron Age sites on Putten, around the Bernisse, none has yet been excavated. Three sites were sampled in outcrops of settlement layers in slopes of ditches. The site of Zuidland 17-27 yielded most crop plant remains. As in the Early and Middle Iron Ages, both barley and wheat are important cereals. Linseed is also conspicuously represented, gold of pleasure only to a lesser extent. Evid-

ently, this spectrum closely connects to those from the earlier sites.

The Late Iron Age site near Rockanje showed a much stronger focus on barley than on wheat. The numerous internodes of barley found suggest the local cultivation of this crop. Linseed and gold of pleasure are also well represented by threshing remains, also suggesting a local cultivation. The environment of the site is much more influenced by salinity than that around the Bernisse. The fact that barley, linseed and gold of pleasure can all be cultivated in salt marsh surroundings (see 6.1) indicates that these crops found in Rockanje indeed could have been grown by the inhabitants themselves. Whether this also applies to the scarce wheat remains must still be questioned.

The steady increase of the sizes of the farms through the Iron Age indicates that the importance of pastoralism was certainly not declining. Exchange may still have been practised in the Late Iron Age. The abundance of pottery connected with salt production in the Late Iron Age site of Rockanje can be seen as an indication of export of salt (cf. Van den Broeke 1986, 1987). Import most likely concerned non-food products, seeing the considerable potential local production of animal and vegetable food products.

The numerous crop processing by-products found in the Late Iron Age sites do attest to the permanence of the inhabitation on Voorne-Putten during this period.

6.5.4 THE ROMAN PERIOD

The two Roman settlements that could be investigated for botanical macroremains, Nieuwenhoorn and Rockanje, are both situated on Voorne. On both sites, the crop plant remains are dominated by barley. Wheat plays a very subordinate role and linseed and gold of pleasure are of little or no importance. The few Celtic beans found in Nieuwenhoorn may point to a much greater role for this crop, considering the low chance of preservation. The fact that Celtic beans can be grown on peaty soils (see 6.2.8) fits in well with the assumption that this crop was cultivated near Nieuwenhoorn. However, the bean straw that would unambiguously evidence local cultivation, was not found.

In Rockanje, the abundance of barley internodes, the ubiquity of crop weeds and the presence of a large granary must be interpreted as evidence for the local production of barley near this site. The Roman site near Rockanje must have been situated in a salt marsh environment, in view of the importance of plants from such habitats among the macroremains. The fact that barley is the predominating crop found on this site agrees well with a local production in such a salt marsh environment. In view of the experiments in the salt marshes near Groningen and Cappeliersiel, and the ubiquity of *Camelina sativa* and *Vicia faba* in other coastal settlements, these crops could also be expected in Rockanje. Their absence might indicate a stronger focus on

barley on this site. It may be concluded that in Rockanje indeed only a small part of the potential spectrum of crop plants was cultivated. This indicates a kind of specialization as far as arable products are concerned. The fact that the house plans in Rockanje are considerably smaller than those in Nieuwenhoorn indicates a differentiation in the importance of stockbreeding during the Roman Period.

Several authors have discussed the consumption of barley by Roman soldiers. According to Davies (1971: 123), barley was destined for the horses in the Roman army. Usually, barley was given to man only as a punishment, while normally wheat was consumed. Groenman-van Waateringe (1989) also stressed the importance of wheat for the Roman military diet. The predominance of barley over wheat in the native Roman settlements is therefore remarkable. In the salt marsh area near Rockanje, wheat could not be cultivated successfully, as is evidenced by recent agricultural experiments, nor could it be cultivated on the peat around Nieuwenhoorn. Barley may have been exported to the Roman *castella* as food for horses. One such *castellum* may even have been present near Oostvoorne (see 1.3.1.4). Alternatively, the inhabitants of Rockanje may have been horse breeders themselves. Unfortunately, the faunal investigations on this site are very scanty. The horse skeletons in the well may reflect the importance of horse breeding, but an unambiguous proof is not provided by this probably non-representative evidence.

6.6 The consumption side of the economy

In an autarkic subsistence economy, the inhabitants of a particular site are the consumers of the agricultural products produced by themselves. Production and consumption are in balance with each other. Whether this type of economy existed on Voorne-Putten during the Iron Age and the Roman Period must be assessed through comparison of estimates both of production and of consumption. A large complication is that prehistoric consumption is even more difficult to estimate than production (cf. Dennell 1979).

The usual way to estimate consumption is via the extant nutritional needs of man, mostly in terms of energy requirements and the amount of essential amino-acids needed. The energy and protein requirements most often cited are those published by the World Health Organization (Passmore *et al.* 1974). These data are separated by sex and age-group (see table 34). Unfortunately, the calorific requirements can be fulfilled by a virtually endless list of possible combinations of food products. Energy may be provided by any foodstuff and a shortage will result in a so-called quantitative malnutrition.

Essential amino-acids are those amino-acids that cannot be synthesized by man. They have to be acquired through food. Animal products provide all the essential amino-acids, whereas vegetable products are deficient in some. In this

Table 34. Energy and protein requirements according to the W.H.O. (Passmore *et al.* 1974).

	Energy (kcal)	Protein (gr)
Children		
< 1 yr	820	14
1-3 yr	1360	16
4-6 yr	1830	20
7-9 yr	2190	25
Male		
10-12 yr	2600	30
13-15 yr	2900	37
16-19 yr	3070	38
adult (moderately active)	3000	37
adult (very active)	3500	37
Female		
10-12 yr	2350	29
13-15 yr	2490	31
16-19 yr	2310	30
adult (moderately active)	2200	29
adult (very active)	2600	29
pregnant females	+ 350	38
lactating females	+ 550	46

respect, cereals and leguminous seeds supplement each other. Regular consumption of both is needed in a vegetarian diet. A shortage of one or more essential amino-acids results in qualitative malnutrition.

For the provision of energy, grain would have been the most important plant food. So as to be able to estimate the total amount of energy required by one household and by the total population in the Voorne-Putten area during the three phases of the Iron Age and during the Roman Period, the number of inhabitants per household and the total number of synchronous households in each phase/period must be assessed. These calculations are shown in paragraph 6.6.1.

6.6.1 SIZES OF HOUSEHOLDS AND POPULATION DENSITY

The number of inhabitants per household can only be estimated. A number used frequently for the later prehistoric and the Roman Period is six persons (Brandt 1976; Bloemers 1978). Haarnagel (1979) assumed 6-8 persons per household.

Prummel (*in press*) assumed a relationship between the number of stalls present in a farmstead and the number of human inhabitants. However, differences in status are well-known from the Iron Age onwards and the differences in the numbers of stalls and thus in the number of cattle, in my opinion, may also be a reflection of the status of the inhabitants.

A different approach to establish the number of inhabitants was explored by Kossack *et al.* (1975: 307; see also Harck 1984). They counted the number of items of types of

Table 35. Areas of the living quarters and total areas of the excavated farms on Voorne-Putten and the inferred number of inhabitants.

Site	Area living quarters (m ²)	Total area (m ²)	Share living area (%)	Inhabitants Naroll	Inhabitants Cook & Heizer
R.H. 10-69	27.1	46.7	58.1	3	2
Sp. 17-30	43.7	81.5	53.6	4	3
Sp. 17-35	31.4	73.1	43.0	3	2
Sp. 17-34	≤ 41.2	≤ 110	37.4	4	3
Ro. 08-52	57.3	121.8	47.0	6	4
Si. 17-24 (1)		79.1			
Si. 17-24 (2)		141.7			
Nh. 09-89 (1)	81.4	152.4	53.4	8	6
Nh. 09-89 (2)		129.6			
Nh. 09-89 (3)	87.7	194.6	45.1	9	6
Rock. II (2a)	?	42	100?	≤ 4	≤ 3
Rock. II (2b)		120			
Rock. II (3)	?	66	100?	≤ 6	≤ 5

pottery that have an individual character (e.g. cups, plates) for a burnt-down farm on Archsum on Sylt (northern Germany), which dates from the Roman Iron Age. It appeared that all the types were represented by six or seven specimens. They concluded that this house was inhabited by seven persons. Apparently, this family was not considered to be hospitable to visitors!

A third way to estimate the number of inhabitants of a farm relates the number of persons (P) to the area (A) that they would require. Bakels (1978) reviews the relationship between P and A that have been proposed in the literature. For farms, the equation of Naroll (1962) and the model published by Cook and Heizer (1968) can be applied. Naroll assumed that each person requires 10 m², so $P = A/10$. Cook and Heizer stated that the first six inhabitants of a house require 150 sq. feet each (13.93 m²), every following person would need another 100 sq. feet (9.28 m²). When these data are applied to the living area of the excavated farms on Voorne-Putten, the number of inhabitants can be estimated. The results are presented in table 35.

It is interesting to note that the number of inhabitants of the Early and Middle Iron Age farms is lower than six. The numbers according to Cook and Heizer's model seem unrealistically small. The numbers of inhabitants according to Naroll's model seem more realistic. Therefore, four and six inhabitants will be used as alternatives for the number of inhabitants of Iron Age farms. The number of inhabitants of the larger Roman farms in Nieuwenhoorn may well have amounted to eight. The size of these farms are in the upper range of what Haarnagel (1979) published for Feddersen Wierde. The smaller farms in Simonshaven and Rockanje probably had considerably fewer stalls. For the Roman Period, six and eight inhabitants will be used as alternatives.

The population density is the product of the number of inhabitants per household and the number of synchronous

households. The number of synchronous households is very difficult to quantify. Van Trierum (*in press*) presented an overview of all the sites known on Voorne-Putten up to and including 1991. He stated that some of these sites cannot be interpreted as former settlements with certainty. His criteria for a settlement are that at least five "find-units³" must have been found. In consequence, two redeposited sherds in a Dunkirk III gully do not represent a settlement, nor do the Roman culverts.

According to Van Trierum's criteria, five Early Iron Age settlements are known to date. All are situated in the area around the Bernisse. From the Middle Iron Age, 25 settlements are known from the Bernisse-area, seven are situated along the Meuse and three on the western part of Voorne. One settlement near the Bernisse belongs either to the Early or to the Middle Iron Age.

The Late Iron Age yielded fifteen settlements in the area around the Bernisse and eight on western Voorne. Furthermore, one settlement near the Bernisse and three on western Voorne belong either to the Middle or to the Late Iron Age. To date, the Roman Period settlements amount to 29 in the Bernisse area, 46 on western Voorne and 4 along the Meuse. Figure 8 shows the locations of these settlements per phase/period.

The number of known settlements, of course, is only part of the number of settlements that really existed. The fact that new sites are still being discovered clearly illustrates this. From 1976 onwards, the intensity of surveys and excavations has increased considerably. In figure 63, the yearly increase in known numbers of sites (not only settlements) between 1976 and 1990 is presented, based on the publication of Van Trierum *et al.* (1988) and Döbken *et al.* (*in press*).

The curve for the Early Iron Age seemingly shows a saturation, the increase stops in 1986. However, the archaeological visibility of the Early Iron Age is lower than

Early Iron Age

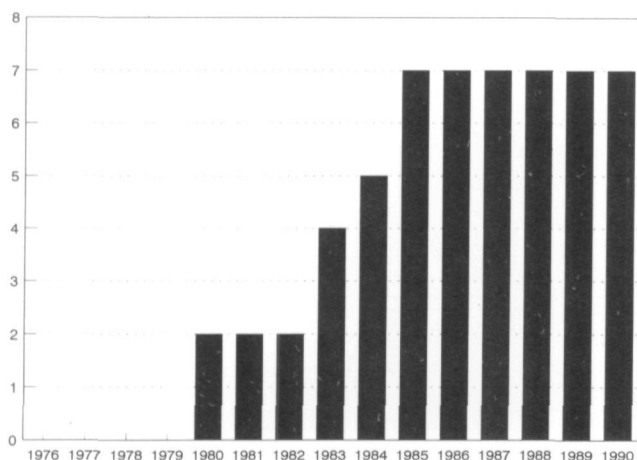


Fig. 63a Yearly increase in number of sites known from the Early Iron Age.

Late Iron Age

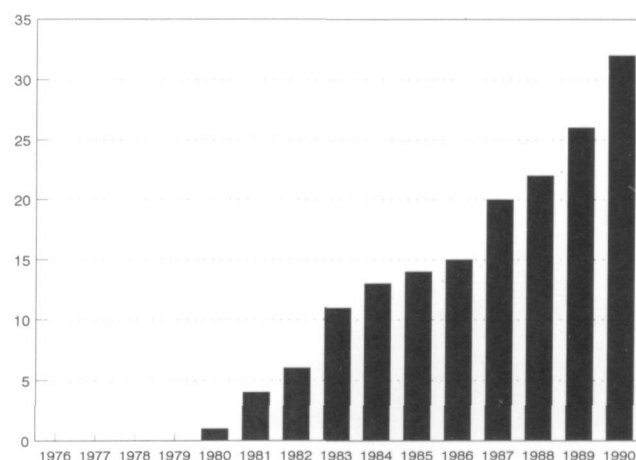


Fig. 63c Yearly increase in number of sites known from the Late Iron Age.

Middle Iron Age

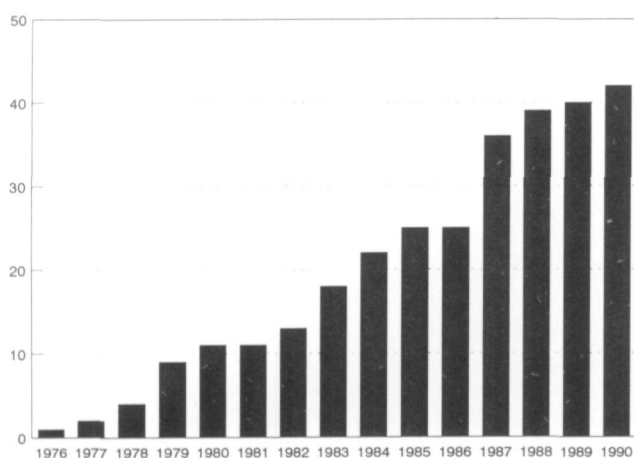


Fig. 63b Yearly increase in number of sites known from the Middle Iron Age.

Roman Period

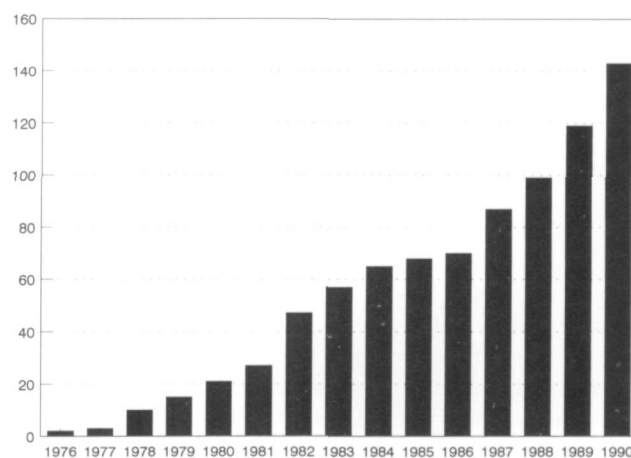


Fig. 63d Yearly increase in number of sites known from the Roman Period.

that of the later phases due to the thin habitation layers that have developed on these sites. The discovery of new sites is very much dependant of large-scale activities, such as house-building, which became less after 1986 in the area around the Bernisse. For the remaining phases of the Iron Age as well as for the Roman Period, it seems clear that the increase is so regular that the curve does not show any sign

of saturation. The discovery of new sites will mainly depend upon such factors as the intensity of surveys and corings (which also yields new sites), the occurrence of realloiments, etc. Besides, some areas have not been subjected to surveys to date, e.g. the area west of Brielle (cf. Van Trierum *in press*). Even intensive surveys may only yield a fraction of the sites found during large-scale construction work, as was

demonstrated by Van den Broeke (1991) for the Iron Age habitation in the peaty area in Midden-Delfland, just north of the Meuse estuary. According to Van Trierum (*pers. comm.*), the known number of sites on Vorne-Putten should probably be multiplied by three to five to give an estimate of the true number.

Within each phase, settlements are not necessarily synchronous. The number of synchronous households may be assessed with the aid of the total duration of each period and an estimation of for how long each settlement was inhabited. According to Van Trierum (1986), the Early Iron Age habitation occurred between 725 BC and 525 BC, so this phase lasted ca. 200 years. The Middle Iron Age, from 425 BC to 200 BC, lasted ca. 225 years and the Late Iron Age, from 200 BC to 25 BC, lasted ca. 175 years. The Roman habitation on Vorne-Putten presumably started around 50 AD and ended between 200 and 260 AD, so it lasted 150-210 years.

It is of further relevance that the Iron Age settlements consisted of single farmsteads. In view of the thin habitation layers found on the Early Iron Age settlements, they were inhabited for a shorter period than their Middle Iron Age counterparts (see *ch. 1*). The durability of the building wood suggests that the farms could not survive longer than ca. twelve years, probably even less than five years. This implies that $200/12 = 16.7$ or even $200/5 = 40$ sites may have occurred during the Early Iron Age without any of them being contemporaneous. The five settlements known to date are considerably less. Even a multiplication of this number by three to five, as suggested by Van Trierum, still does not necessarily imply synchronous sites.

The duration of the Middle Iron Age farms is hardly supported by wood identifications. The only excavated Middle Iron Age site also studied for wood remains, Spijkenisse 17-34, mainly yielded wood from the wall. Central roof-supporting elements, which on other sites were made of relatively durable wood species (see *ch. 3*), are hardly present. However, it does seem probable that oak wood was not used commonly, since it does not occur among the wood remains studied from Spijkenisse 17-34. In view of the preservation of waterlogged organic material, the environment will have been wet. Therefore, it seems highly probable that the Middle Iron Age site of Spijkenisse 17-34 did not last significantly longer than 10 years. Taking into account a duration of 225 years for the Middle Iron Age, the 25 known settlements in the area of the Bernisse just cannot be all asynchronous. If the number of sites is multiplied by three to five, three to six sites may have occurred synchronously in the area around the Bernisse. The three settlements on western Vorne, probably representing nine to fifteen settlements, may all have been asynchronous. This also applies to the seven (probably representing 21-35) sites

along the Meuse. According to Van Heeringen (1992: 231), six to twelve synchronous settlements may have occurred on Vorne-Putten during the Middle Iron Age.

The durability of wood in Late Iron Age settlements cannot be assessed. However, a preliminary wood research of the Late Iron Age site of Rockanje 08-52 demonstrated that ash predominates among the crucial construction elements. Besides, even birch was sometimes used for roof supports. A durability of ten years at the very best seems likely. The fifteen known settlements near the Bernisse may all be asynchronous, as the Late Iron Age lasted 175 years. If this number of settlements is multiplied by three to five, two to four settlements would have been synchronous. The eight settlements known from western Vorne may represent two or three synchronous households in that area.

The duration of the Roman settlements may have differed considerably from the Iron Age ones. Firstly, oak wood was more regularly used as building material. Secondly, the excavated sites near Nieuwenhoorn and Simonshaven revealed houses one on top of the other, which considerably increases the duration of the settlements at these sites. Thirdly, in Rockanje, houses were built next to each other. Of the three houses studied for botanical macroremains, one seems to be asynchronous, but the remaining two probably were occupied simultaneously. These data indicate that the duration of Roman sites may well have been between 50 and 100 years. Without evidence for the other settlements, which mostly have not been excavated, an average duration of 50 years is assumed for the Roman settlements. As the Roman habitation lasted 150-210 years, the 29 known settlements in the area around the Bernisse represent seven to ten synchronous settlements, which may be three to five times as many when corrected for unknown settlements. The 46 known settlements on western Vorne similarly may represent 15 or 45-75 simultaneously inhabited houses. The four sites along the Meuse may represent one or four to six synchronous households. The large increase in the number of settlements between the Late Iron Age and the Roman Period is striking. Archaeological visibility cannot be the only explanation, as the Late Iron Age sites around the Bernisse are located upon the same Dunkirk I deposits as the Roman ones, while the increase occurs in this area as well. An ecological explanation does not appear from the present study either. The large-scale relocation of autochthonous inhabitants during the start of the Roman occupation (see 1.3) might provide an archaeological explanation.

6.6.2 THE AREA AVAILABLE FOR ARABLE AND PASTORAL FARMING

The levees along the Meuse had the soils best suited for arable farming on Vorne-Putten during the Early and Middle Iron Age. The width of the Meuse levees can be set at 100 m. This may seem rather narrow for a large river as

the Meuse. The levees along the Ems are several kilometres wide (see 2.5.3). In the Meuse basin, however, there is not enough space for such wide levees. The Dunkirk III gully, which completely eroded the Iron Age Meuse with its levees, had a width of 600 m. The river plus its levees should fit into this width. Thus, the width of the levees cannot have been far in excess of 100 m. The palynological investigations demonstrated that the transition from fresh to brackish conditions was near Heenvliet (see 2.5.3). The levees east of this transition are in a fresh water environment, covering 10 km on Voorne-Putten. West of this transition levees lay in a brackish to saline environment, which covered ca. 25 km. At a width of 100 m, the 10 km stretch of levees in the freshwater area provides 100 ha of arable land, the 25 km in the brackish or salt area covers 250 ha. The total area covered by these levees thus amounted to ca. 3.5 km², a very small part of the ca. 193 km² of Voorne-Putten.

The peaty area on Voorne-Putten during the Early and Middle Iron Age will mainly have been used for pasture (if used anyway). The area covered by the Holland peat has been assessed by digitized maps (see *fig. 4*). Unfortunately, the total area of peat during the Early and Middle Iron Age cannot be assessed. The Holland peat occupies ca. 124 km² of the 149 km² represented on the geological map 37 West (see also *fig. 4*).

The situation during the Late Iron Age and the Roman Period is very different owing to the deposition of Dunkirk I sediments (see *fig. 5*). Clayey deposits, which are favourable for arable farming, cover ca. 41 km² on western Voorne and 7.2 km² in the area around the Bernisse. Peat covers 77.8 km² during the Roman Period.

6.6.3 THE SUBSISTENCE PATTERN OF THE SINGLE FARMS
The requirements of a single household in terms of calorific and protein consumption will have been fulfilled by a combination of animal and vegetable sources. The mutual share of these sources is extremely difficult to quantify through archaeological data. Estimates are therefore often used. However, as Fokkens (1991) indicated, such estimates may range from 90% to 40% vegetable products.

The arable/pastoral ratios on the basis of palynological data do not offer a reliable alternative for estimating the importance of these components. The more sophisticated pollen-ratios indicate over 90% of pastoral products, which is extreme. These ratios are most probably influenced by taxa that are of small relevance (see *ch. 2*). Both render these percentages doubtful.

The ratios on the basis of botanical macroremains, proposed in chapter 4, seem to indicate differences between the sites. The precise values cannot be expected to represent the factual importance of arable and pasture for the sites investigated, but the trend in the data is remarkable (see *table 30*). The frequency ratios indicate that stenoecious arable

weeds are absent in Spijkenisse 17-30. The role of arable farming was probably less important than in the other sites. Unfortunately, the Early Iron Age site of Rotterdam-Hartelkanaal yielded too few data to allow calculation of a reliable ratio. The Late Iron Age sites show higher frequency ratios than their earlier counterparts, which can be seen as an indication for the increased possibilities for arable farming on the Dunkirk I sediments. The ratio of Rockanje 08-52 does not differ markedly from that of the Late Iron Age sites around the Bernisse. The fact that Dunkirk I sediments had not yet been deposited during the Late Iron Age habitation in Rockanje is apparently not of great influence in the roles of arable and pastoral farming.

The Roman site near Nieuwenhoorn shows a much lower ratio than the Late Iron Age sites and the Roman site of Rockanje. The latter site shows the highest ratios of all sites investigated. The large farms, probably with many stalls, in Nieuwenhoorn and the much smaller house plans in Rockanje do agree with this observation. Both point to differences in the agricultural economies of these native Roman settlements.

For quantification of past economies, it seems best to work with the only reliable quantitative information, the number of stalls in the farms. These provide information about the number of animals kept, although this may be a minimum number since not all the animals necessarily had to be housed. On the basis of this number, the meat supplied by these animals can be assessed, as Prummel did for hypothetical Iron Age farms on Voorne-Putten (see *ch. 5*). The proteins and calories supplied by these animal sources may subsequently be evaluated in terms of remaining needs to be fulfilled by vegetable products. The area needed for keeping the animals involved and for growing the vegetable products can then be calculated and compared with the available area. A similar sequence of analysis was conducted by Gross *et al.* (1990) for Neolithic lakeside villages in Switzerland. However, these authors did not use the number of stalls but the Minimum Number of Individuals for the domesticated animals based on bones found. For Voorne-Putten, this method cannot be applied due to the decay of bone in the mainly peaty sediments.

In view of the differences in archaeological data from the Iron Age and the Roman Period, they will be discussed separately in the following sections.

6.6.3.1 The Iron Age

Prummel (*in press*) has drawn up a table to estimate the yearly meat supply for Iron Age farms on Voorne-Putten (see *table 32*). She assumed that the larger farm, with ten stalls, was inhabited by eight people. The data discussed in 6.6.1 indicate that this number is probably too high. Hereafter, the number of inhabitants will be set at four and six as alternative variables in the assessment of the dietary

Table 36. Provision of energy and proteins in model Iron Age farms.

Number of stalls	6	6	10	10
Number of inhabitants	4	6	4	6
Energy provided by animal products ($\times 10^6$ Kcal))	1.5-2.1	1.5-2.1	1.8-2.6	1.8-2.6
Energy required per year ($\times 10^6$ Kcal)	3.1	4.8	3.1	4.8
Share covered by animal products	47-67%	31-44%	58-84%	38-54%
Proteins provided by animal products (kg)	34-48.5	34-48.5	47.5-69	47.5-69
Proteins required per year (kg)	37	64	37	64
Share covered by animal products	91-100%	53-76%	100%	74-100%
Required amount of grain (kg)	300-455	850-1030	150-395	665-910
Required area in ha (yield 1:7)	0.8-1.3	2.4-2.9	0.4-1.1	1.8-2.5

needs. The main variables discussed below have been assembled in table 36.

First, these dietary needs of inhabitants of a small hypothetical farm, with six stalls, will be estimated. According to Prummel, two to three head of cattle could be slaughtered yearly. Each head may have provided 478,200 kcal. The protein content amounts to 10 kg for the 60 kg of meat with 168 g protein/kg. Sheep will also have provided meat. Prummel stated that one sheep may have been slaughtered yearly. This would have yielded ca. 68,370 kcal, proteins would amount to 1.5 kg (9 kg of meat, 170 g of proteins/kg; cf. *Voorlichtingsbureau voor de Voeding* 1980). Prummel further estimated that one or two piglets were slaughtered yearly. She based this estimate on a litter size of only two. In view of IJzereef's estimated litter size of six, the number of slaughtered pigs and piglets may have been higher. However, the proportion of pig bones does not suggest a greater importance of pig relative to sheep. The age of slaughter of pig indicates that adult pigs were consumed as well, so the slaughter of one pig and one piglet per year will be assumed here. These probably provide a minimal estimate. These animals will provide 270,000 kcal. The 30.5 kg of meat provides ca. 5 kg of proteins.

In total, these animals may have provided the inhabitants of the smaller farm with 1.3-1.8 million kcal, and with 25-36.5 kg of proteins. The role of milk in the diet of our household is also estimated by Prummel. She arrived at a yearly net yield of 300-400 kg milk from cows and 50 kg milk from sheep. The milk-yield of 100 kg per cow per year used by Prummel is low, but will be followed here to assess a minimum value. The 300-400 kg correspond to 180,000-240,000 kcal and to 9-12 kg protein. The 50 kg of milk of sheep corresponds to 50,000 kcal and 1.5 kg protein.

The dietary demands of the inhabitants depends upon their age and sex. A low level and a high level of requirements will be used here, to explore the limits of the agricultural system. A low level is needed by four inhabitants. To provide a base for calculations, it will be assumed that this hypothetical family consisted of one moderately active male plus one female, one child of 1-3 years old and one of 4-6

years old. According to data of the World Health Organization (W.H.O.; see table 34), the daily requirements of this household amounts to 8390 kcal and 102 g protein. This corresponds to yearly figures of 3.1 million kcal and 37 kg protein. If the farm was inhabited by a model family of six persons plus one baby, one moderately active male plus a lactating female, and two other children of 1-3 and 7-9 and a subadult male of 13-15 years old respectively, the daily requirements amount to 13,020 kcal and 175 g proteins, or 4.8 million kcal and 64 kg protein per year.

These data indicate that the protein requirements of four inhabitants could be provided by meat and milk alone. The 1.5-2.1 million kcal provided by meat and milk are ca. 1-1.5 million kcal below the needs. Thus, in this case meat plus milk may have provided 47-67% of all the energy required. The remaining 1-1.5 million kcal must have been obtained through vegetable products. This amount corresponds to 300-455 kg of grain (3300 kcal/kg). This yield can be obtained from ca. 1 ha of arable. If 60 kg/ha is sown in rows, a yield of 1:6 to 1:8.5 is sufficient (including grain for sowing next year). If 200 kg/ha is sown broadcast, a yield of 1:2.5 to 1:3.3 is sufficient.

The protein requirements of six inhabitants plus a baby, 63.9 kg per year, cannot have been provided by animal products alone. The 35.5-50 kg protein fall 13.9-28.4 kg short. The 1.5-2.1 million kcal produced by meat and milk are ca. 2.7-3.3 million kcal below the needs. In this model, meat plus milk may have provided 31-44 % of the total calorific needs. If the remaining calories are to be provided by grain, ca. 850-1030 kg is needed. This amount of grain would provide 76-216 kg protein (barley at least 9%; emmer at most 21% of protein) so that this requirement is also covered. At a yield of 1:7 and planting in rows, 2.4-2.9 ha are required to produce these calories, in broadcast sowing and a yield of 1:3.5, a maximum of 2.1 ha will be sufficient.

After the above calculation for a farm with six stalls, the food production of a larger farm, with ten stalls, will be estimated, again for the above-mentioned model households of four and six persons plus a baby.

According to Prummel (*in press*), three to five adult head

of cattle could have been slaughtered yearly. However, her age-class distribution for cattle demonstrates that 35% of the cattle was slaughtered between the ages of 1-3.5 years. Thus, the three to five head of cattle are here assumed to have been two to three adults and one to two heifers.

The number of sheep slaughtered per year probably amounted to one adult and one lamb per year (Prummel *in press*). As far as pigs are concerned, Prummel assumed that one adult pig and one piglet were slaughtered per year on a farm with ten stalls. In view of the low litter size assumed by Prummel, this will be used as a minimum value here. The energy provided by these two animals amounts to 270,000 kcal. The proteins amount to 5 kg.

In total, meat may have provided the inhabitants of the larger farm with 1.5-2.1 million kcal and with 32.5-48 kg proteins per year. The quantity of milk on this larger farm, as indicated by Prummel, may have been 400-500 kg from cows and 100-200 kg from ewes. Again, these may represent conservative estimations. This corresponds to 240,000-300,000 kcal and 12-15 kg protein for cows milk and to 100,000-200,000 kcal and 3-6 kg proteins for ewes milk.

The 47.5-69 kg protein provided in total by milk and meat are sufficient for four inhabitants, while the upper range may also have been sufficient for six inhabitants plus a baby, who probably need 64 kg protein per year.

The 1.8-2.6 million kcal are 0.5-1.3 million kcal below the requirements of four inhabitants. Animal products in this case may have provided 58-84% of the total calorific needs. The remaining calories are equivalent to 150-395 kg of grain, which of course requires even lower yields as calculated for the four persons in a house with six stalls. If six persons and a baby inhabited the farm with ten stalls, the calories derived from animal products would be 2.2-3.0 million kcal short of their requirements. Therefore, animal products constitute 38-54% of the total calorific requirements. To supply the remaining calories by grain, an amount of 665-910 kg of grain is needed. If 60 kg/ha is sown in rows on one ha, a yield of 1:12 to 1:16 must be reached. Broadcast sowing of 200 kg/ha requires a yield of 1:4.3 to 1:5.5 if one ha is sown. As yields above 1:7 in sowing in rows and above 1:4 in broadcast sowing (see Sigaut 1992: 403) may not have been feasible, a greater area had to be sown. If three ha are sown, ratios of are 1:4.7 to 1:6 and 1:2.1 to 1:2.5, respectively, are appropriate.

The feasibility of the required yields is mainly determined by the time needed for planting and harvesting the crops and the area required for arable fields. These aspects will be discussed in the following paragraph (6.6.5).

When applied to the site of Rotterdam-Hartelkanaal, which had six stalls, these calculations demonstrate that the calorific requirements cannot have been fulfilled by animal products alone, neither for six nor for four inhabitants. If it is maintained that the inhabitants of this site did not grow

their own cereals, it follows that they must have imported calories, which may well have been in the form of cereals. It implies that the inhabitants had to develop an obligatory relationship for the import of food products, for instance with cultivators of cereals. Even if the peat dwellers exported some of their products, this relationship remained asymmetric in terms of calories, as cereal-growers export more calories than they import.

The very low population density in the peaty area during the Iron Age is of relevance in this context. The number of people is far too low to form a separate, independent population (marriage group). According to Hassan (1981: 61), a mating pool must have at least 175 individuals to be able to subsist independently. Birdsell (1973) mentioned a group size of ca. 500 persons needed for independent existence, Kosse (1990: 280) arrived at group sizes around 350-400 individuals. Waterbolk (1979: 4) assumed a minimum group size of a few hundred persons. Thus, ties of the peat-dwellers on Voorne-Putten with inhabitants in adjacent areas, such as the levees and/or the dunes, were a necessity from this point of view too.

Pottery does not provide evidence for relationships with the Pleistocene hinterland. According to Van Heeringen (1992: 302)

"the similarities in the pottery suggest that the occupants of these areas [i.e. the peaty areas along the Meuse] maintained close social contacts with the occupants of the Older Dunes".

The second excavated Early Iron Age site, Spijkenisse 17-30, also has six stalls, so the inhabitants again could not fulfil their own calorific requirements with animal products alone. Thus, they must either have grown their own crops or had to import them. In contrast to Spijkenisse 17-35, cultivation of crops by the inhabitants of Spijkenisse 17-30 could not be ascertained.

The Early Iron Age inhabitants of Spijkenisse 17-35, a farm with ten to twelve stalls, were probably self-sufficient. Barley and linseed were grown by the inhabitants themselves, in view of the threshing remains that only occur on production sites. Emmer does not occur in the Early Iron Age samples from this site. This is also the crop least likely to grow on peaty soils. Whether or not barley and linseed can indeed be grown on drained fen peat, however, does deserve experimental cultivation on such soils. The presence of exclusively summercrop weeds in the samples suggests that the rich soils of the levees along the Meuse are more likely candidates for the Early Iron Age arable fields. Cultivation of crops on peat does not necessarily demand cultivation as a summercrop. Moreover, weeds of acid soils, e.g. *Spergula arvensis*, would be expected if cultivation of crops on peat was practised.

The Middle Iron Age materials from Spijkenisse 17-34 and 17-35 and from Geervliet 17-55 all suggest cultivation of

several crops by the inhabitants themselves. All sites seem to have been autarkic in their food production. Again, cultivation of crops on the mineral soils along the Meuse is most likely.

Interestingly, according to Van Heeringen (1992) and Van Trierum (*pers. comm.*), the Middle Iron Age pottery from Voorne-Putten seems to stand on its own. There are no clear relations with other areas. This would also plead for a self-supporting system during the Middle Iron Age, but the population density still will have been far too small to form a separate marriage-group.

The only excavated Late Iron Age farm, near Rockanje, has twelve stalls. Emmer, barley, gold of pleasure and linseed all occur frequently in the samples for macroremains. Again, by-products characteristic for production sites have been found of barley, gold of pleasure and linseed. Emmer does again not provide conclusive evidence.

In the samples from the unexcavated Late Iron Age sites near the Bernisse, local production of the first three mentioned crops is also demonstrated. In view of the improved agricultural conditions during the Late Iron Age, as a result of Dunkirk I deposits, self-sufficiency during this period can be concluded. Even more so than in the Middle Iron Age, however, the population in this area is too small to be independent. Contacts with inhabitants of the levees along the Meuse and the dune area must have persisted throughout the Iron Age.

6.6.3.2 *The Roman Period*

The Roman settlements lack some of the crucial information used for the Iron Age sites discussed above. Firstly, the excavated farms do not show the well-defined stalls. One possibility to reconstruct the byre-parts of these farms is by measuring the distances of the roof supports. It has often been noticed that these distances are smaller in byre-parts (e.g. Haarnagel 1979). The plans of the settlement of Nieuwenhoorn 09-89 are the only native Roman ones on Voorne-Putten that can be used in this respect. In the first phase farm, the posts in the byre area are 3 m apart, in the third building phase this distance is 3.20 m. These distances are considerably wider than the distances for "double" stalls reported by Waterbolk (1975) for Roman farms. One possibility is that the byres in Nieuwenhoorn were not for cattle, but for caprovids. This may explain the absence of clear partitions too. Unfortunately, any support for this assumption, based on the importance of sheep/goat remains among the bones is wanting. The investigation of the bone remains from Nieuwenhoorn may in the future provide important information. The faunal remains from Roman sites studied by Van Mensch do indicate an increased importance of sheep/goats, but cattle is still predominant.

Secondly, the fact that slaughter ages of bones from Roman sites have not been established, poses further limita-

tions when compared to the Iron Age situation. As a result, the role of animals in the diet of the inhabitants of Voorne-Putten during the Roman Period is very uncertain. In view of the sizes of the farms it will be assumed here that the herds were not smaller than those of the hypothetical farm with ten stalls in the Iron Age. The amount of livestock that could be housed in this farm will be used for the Roman situation. The importance of sheep will not be assumed to have been higher here, as the increased number of finds may have been caused by better preservation conditions.

Thus, as in the Iron Age farm with ten stalls, meat and milk may have provided 1.8-2.6 million kcal and 47.5-69 kg protein.

In view of the larger sizes of the native Roman farms, the number of inhabitants will have been between six and eight rather than four. These six inhabitants and a baby required 4.8 million kcal and 64 kg protein per year. In consequence, the amount of proteins derived from meat and milk would have been more or less sufficient. The calorific content of meat and milk may again have provided 38-54% of the needs.

A household with eight inhabitants may have consisted of two adult males and one pregnant female, a fourteen year old male, a twelve and a ten year old female and two children of seven and three years of age. They will have needed ca. 7.2 million kcal and 91 kg protein per year. The proteins from animal products could have covered 52-76% of the requirements, the calories 25-36%.

Granaries from the Roman period were discovered at Rockanje and Simonshaven. If we assume that these granaries did serve for storage of grain, the storage capacity can be assessed. The potential amount of grain that can be stored, and the amount of calories it represents, may give an insight into the grain production.

In order to calculate the amount that could be stored, it is assumed that in the Iron Age and Roman Period, storage took place in the chaff (see 6.4.2), probably with the exception of military Roman contexts, which are not of relevance here. My own measurements showed that barley grains have a density of 837 kg/m³, of which ca. 1% is chaff (the more voluminous internodes would have been discarded before storage), leaving ca. 829 kg available for consumption. In the case of wheat, grains have a density of 852 kg/m³. The glumes of emmer are much denser than the hulls of barley. Measurements demonstrated the share of emmer glumes plus internodes on basis of weight to be 20%. Thus, 710 kg/m³ remains for consumption. Evidently, the better preservation of hulled wheats stored in chaff is at the expense of the storage capacity.

Davies (1971 citing Haverfield 1920) stated that one ton (2240 lb = 1017 kg) of (unspecified) grain required a storage capacity of 1.5 yd³ = ca. 1.1 m³, corresponding to a density of 925 kg/m³. Reynolds (1974 cited in Mercer

1981) found that in a silo of 1.2 m^3 an amount of 1120 kg of threshed, modern barley could be stored, corresponding to 933 kg/m^3 . The difference with my measurements is probably caused by a difference in moisture content of the grains. As calorific contents are measured on dry seeds, my measurements will be used in the following.

The granary of Rockanje has a floor area of 16 m^2 , the one in Simonshaven of 15 m^2 . It will be assumed here that grain was not stored in sacks or bins, but in bulk. Stored bulks of grain form a cone with an angle of inclination of 30° . A wall surrounding the floor of the granaries would appreciably increase the storage capacity, but cannot be demonstrated archaeologically. Every height of 6.25 or 6.7 cm for Rockanje and Simonshaven, respectively, would increase the capacity by 1 m^3 . Without wall, the capacity of the granary of Rockanje ($4 \times 4 \text{ m}$) is 4.82 m^3 , the height of the cone is $2 \times \tan 30^\circ = 1.15 \text{ m}$. The granary of Simonshaven measures $5 \times 3 \text{ m}$ and has a capacity of 4.64 m^3 . Both these capacities are minimum values.

The storage of grain probably took place in the form of hulled grain. In view of the data presented above, ca. 837 kg of unthreshed barley and 852 kg of emmer could be stored per m^3 . The granary of Rockanje could contain ca. 4034 kg of unthreshed barley, that of Simonshaven 3884 kg of barley or 3953 kg of emmer. These data are for granaries without walls on the floor. If a yield ratio of 1:7 is assumed, 1/7 part of the crop must be reserved for sowing in the next year.

After subtraction of the chaff and the required amount of seed grain, 3490 kg of barley remains for consumption in Rockanje, in Simonshaven 3365 kg of barley or 2880 kg of emmer. The amount of calories provided by the amounts of grain available for consumption can be used to estimate whether or not this stored crop exceeds the requirements of a household. In the case of Rockanje, the amount of barley that can be used for consumption in the granary without a wall equals to 11.1 million kcal. For Simonshaven, this value is 10.7 million kcal for barley or 9.5 million kcal for emmer.

The requirements of eight inhabitants remaining after subtraction of the calories provided by meat and milk are 4.6–5.4 million kcal. The potential overproduction is therefore considerable. If the floor had a wall of only ca. 6.5 cm height, the granaries would provide an additional capacity of 1 m^3 . A wall of ca. 35 cm would increase the storage capacity by 5 m^3 , which corresponds to 3620 kg of pure barley for consumption or 3105 kg of emmer. In that case, the surplus in Rockanje may have been amounted to ca. 17.3–18 million kcal, or over 5400 kg of pure grain. If we assume with Davies (1971: 123) that a Roman soldier consumed one third of a ton of grain per year, corresponding to ca. 3000 kcal/day, the surplus produced by a farm with probably eight inhabitants may have been sufficient for sixteen soldiers. In the following paragraph, it will be calcu-

lated whether this overproduction is feasible in terms of land and labour required.

6.6.4 THE FEASIBILITY OF THE MODELS FOR FOOD CONSUMPTION

The calculations presented in the previous paragraphs are not informative until it is assessed whether the areas of grain required to fulfil the requirements in the Iron Age or to fill the granaries in the Roman Period are feasible. Both the available amount of arable land in the wetland area of Voorne-Putten and the available amount of labour may have been limiting factors. The area of land needed for pastoral farming must also be assessed.

6.6.4.1 *The area of land required*

The area of land that is required for the farms must comprise of both arable and pastoral land. During the Early Iron Age, probably not more than one single farm existed any one time in the peaty area. They are situated in the surroundings of the present Bernisse as other parts of Voorne-Putten have not yielded any traces of Early Iron Age habitation. If the worse archaeological visibility of the Early Iron Age is compensated, few synchronous households may have existed.

In the model, the inhabitants of a large Early Iron Age farm had fourteen head of cattle, two horses, four sheep and two pigs in winter. This number of housed animals had to be provided with fodder. If we assume that 200–225 kg of reed hay per month is needed per head of cattle or horse (see 6.3.1), 3200–3600 kg of reed is required for winter fodder per month. If the animals were housed for four months, the amount required would be 12,800–14,400 kg.

The amount of hay that can be harvested from one ha is estimated by Gregg. The lowest recent hay yields are from natural meadows on low-lying damp soils, where hay yields are 1470 kg/ha (Gregg 1988: 108). However, this estimate is very low. Drost (1986) stated that in reedlands, 7000–12,000 kg of dry matter is produced per ha. Near the Lauwerszee, a production up to 13,000 kg of dry matter was measured in reedlands (Drost *et al.* 1983). These vegetations are better comparable to the ruderalised reed vegetations on Voorne-Putten during the Iron Age and the Roman Period. Since the reedlands cannot have been turned into hay completely, a yield of 3500 kg of reed per ha will be used next to Gregg's hay yield. For the amount of reed hay needed in our Early Iron Age farm with ten stalls, ca. 8.7–9.8 ha are required if Gregg's estimate is used, whereas 3.7–4.1 ha are appropriate if 3500 kg of reed is harvested from 1 ha. The storage of this large amount of reed hay must have required special structures, such as hay-stacks. Their traces would be difficult to recognize in excavations.

For the eight months that cattle and horses fed on pastures, 2–5 ha per individual would have been needed, sheep

require 0.7-1.7 ha of pasture for one year. The 4-7 calves and 2-3 lambs also required pasture. It is assumed here that they required half the amount of adult cattle and sheep, respectively. Therefore, another 4-7.5 ha may have been required for the calves and 0.7-1 ha for the lambs. The total area for grazing for domesticates would amount to 27-70 ha. For grazing plus hay 31-80 ha would be required in the Early Iron Age farm with ten stalls.

The amount of grain needed by six inhabitants and a baby to supplement the calories provided by meat and milk in a farm with ten stalls is 665-910 kg (see 6.6.3.1), while four inhabitants would need 152-394 kg of grain. If we again assume a yield ratio of 1:7 in fields planted in rows with 60 kg/ha of sowing grain, the net yield per ha is 360 kg. For 910 kg, ca. 2.5 ha of arable land are required. Although the levees have a fertile soil, for reasons of certainty a fallow period may be assumed. If allowance is made for a fallow every other year, 5 ha of arable land are needed.

The predominating cereal crops during the Early Iron Age are wheat and barley. Barley may have been cultivated on desiccated peat around the settlement, but this is not very likely in view of the crop weeds found. It will be assumed here that the 5 ha of arable land is to be sought on the deforested levees along the Meuse. The 5 ha of arable land provided roughly the same amount of calories as the 31-80 ha needed for domesticates.

Of the levees of the Meuse, a stretch of ten km length in the northern part of Voorne-Putten lies in the sphere of influence of fresh water, while 25 km lies in the brackish to salt zone. These levees were probably also exploited by settlements on the levees themselves. The fact that the pollen influx diagram of Spijkenisse 17-30 shows a decrease in oak pollen deposition of ca. 80% indicates that a considerable proportion of the *Hartholz-Aue* forest had been felled. As the remaining oaks will have profited from the improved light conditions, the deforested area might even have been more than 80% of the area covered by oaks. This quantity of felling cannot possibly have been achieved by one single Iron Age farm in the peaty area.

Since 5 ha of arable are required for a large Early Iron Age household, the levees along the Meuse (350 ha, see 6.6.3) may have provided arable land for dozens of such farms. Since probably no more than a few farms existed at any one time in the peaty area, the area available will most probably not have been a limiting factor during the Early Iron Age. The amount of reedland available was very large, so this will not have imposed limits.

During the Middle Iron Age, three to four synchronous sites may have occurred in the peaty area, one on western Voorne and one near the Meuse. The available land will have been similar to that during the Early Iron Age. The five or six synchronous households may have had dozens of

counterparts on the levees without the area for arable and pastoral farming becoming scarce.

The number of Late Iron Age farms may have amounted to two to three synchronous farms in the Bernisse area and to two on western Voorne. The area of arable land available is considerably enlarged by 720 ha of Dunkirk I sediments around the Bernisse and 4100 ha on western Voorne. Hundreds of autarkic settlements could have been founded in this area.

The Roman Period shows the densest habitation on Voorne-Putten, with 30 synchronous settlements in the area around the Bernisse, 45 on western Voorne and 4 along the Meuse. Not only reedlands were available for grazing, but for the sites on western Voorne, the salt marsh could also have provided grazing territory.

The amount of animals kept in the Roman Period is assumed to be similar to that in a large Iron Age farm with ten stalls. In the reedlands, 31-80 ha were needed for the domesticates for grazing and winter fodder. Since the grazing density is higher in salt marshes (compare 6.3), the area needed will have been smaller than in reedlands.

If we assume that the granaries were filled each year with grain grown by the inhabitants of the Roman farms, a yield of 2880 kg of pure emmer in Simonshaven or 3495 resp. 3365 kg of barley in Rockanje and Simonshaven (granaries without walls) to 5985-7120 kg of pure grain (granaries with walls of ca. 35 cm) would be required. If grain was planted in rows (60 kg/ha) and the yield ratio was 1:7, each ha would yield 420 kg. In that case, 14.3-17.0 ha of arable fields must have been available to fill a granary with walls. If it is assumed that a fallow was required every other year, which is a very cautious estimate, the area needed for cereals is 29-34 ha.

In the reedland situation, the total area needed in this model amounts to 31-80 ha for animals and to 28.6-34 ha for arable products. The 720 ha of Dunkirk I deposits near the Bernisse, if used for arable fields only, could have supported 21 to 25 farms. If these clayey sediments also were used for pasture, at least six farms could exploit this area. The much larger Dunkirk I sediments on western Voorne (4100 ha), where the salt marsh could have provided part of the grazing territory, could have supported at least 36 synchronous farms.

The estimated 30 farms that were present near the Bernisse thus probably could not all produce the amount of grain needed to fill granaries of the size found in Rockanje and Simonshaven. Besides, they had to reserve the Dunkirk I deposits around the Bernisse for arable fields. The drained peat that covered 7780 ha during the Roman Period must have been used for pasture, an area larger than required.

In contrast, the number of settlements on western Voorne remained far below the carrying capacity of the area for arable and pastoral farming.

6.6.4.2 *The amount of labour required*

In the production of food products, the severest time stress will have been posed by arable farming. Although the management of livestock will have required time spent every day, the large-scale events connected with the cultivation of crops have in many publications been regarded as bottlenecks (e.g. Brandt 1976; IJzereef 1981; Gregg 1988; Gross *et al.* 1990). The amount of reed with forbs to be harvested for hay in late summer may also have required a considerable investment of time.

For hay, it is best to harvest before the seeds ripen, as ripening of seeds lowers the quality of the hay. The presence of many unripe seeds in carbonized hay remains in a Roman horse stable confirms this practice (cf. Knörzer 1979). Most likely, hay was harvested shortly after cereals were.

Beranova (1989) described experimental harvesting of hay with replicas of Iron Age scythes from Bohemia. She calculated that harvesting one ha would require 47.5-62.5 hours. These data agree well with those provided by Steensberg (1979), who experienced that 1750 m² of barley could be harvested in 10 hours with a scythe. This corresponds to 57.5 hours per ha. This figure will be used for reed hay here. The 8.7-9.8 ha needed (according to Gregg) to feed livestock in a farm with ten stalls thus required 50-56 working days of ten hours for harvesting. The 3.7-4.1 ha suggested by Drost's data require 21-24 working days. Since the hay had to be transported and stored as well, the amount of labour required according to Gregg's data is most likely not feasible.

The time needed for ploughing has been assessed by several authors. According to Hansen (1969), ploughing with an ard (Døstrup type) with two trained oxen took place at a speed of 3.6-4.3 km/hr. The prehistoric ard marks found in excavations are ca. 25 cm apart (cf. Zimmermann 1984). This leads to 40 km of furrows for one ha. This means that ploughing and cross-ploughing of one ha requires ca. twenty hours or two working days of continuous ploughing.

According to Steensberg (1986: 143) and Reynolds (1987b), it takes about one day to plough and cross-plough one acre (4050 m²), corresponding to 2.5 days per ha with an ard. Varisco (1982) observed that ploughing with an ard in Yemen took 3.3 days per ha with a span of two oxen. These data may be more realistic than those of Hansen, as turning the oxen and removing large objects were not included in his measurements. Ploughing with a mouldboard plough will have been slightly faster than with an ard. Cross-ploughing with a mouldboard plough is not necessary, but the field cannot be sown in rows after ploughing with this kind of plough. In that case, a drilling-ard would still be required. Alternatively, broadcast sowing and covering the seeds (for instance by raking or harrowing) is possible after mouldboard ploughing.

Ploughing can be carried out over a greater time-span than sowing or harvesting, so it will not have presented a limiting factor in the total area that could have been cultivated.

The time needed for sowing heavily depends on the method used (see 6.2.2). Planting in rows implies that a distance of 40 km must be walked for every ha sown, whereas in broadcast sowing this may have been 2 km. If a speed of 1 km/hr is assumed, 1 ha would require four working days when planted in rows. Sigaut (1992) stated that sowing one ha in rows costs five working days. Moreover, according to him, a whole family has to be involved. A drilling ard would require 1.25 days (it is unidirectional!), but may also replace the cross-ploughing. 0.2 working days are required when 1 ha is sown broadcast. Sigaut (1992) stated that broadcast sowing of one ha takes 0.25 days. Raking, to cover the seeds, may have required another 0.5 days per ha. It is often assumed that one month is available for sowing and one for harvesting. In one month, one person could plant ca. 6.7 ha in rows (or 17.1 ha with a drilling ard), while 42.8 ha could be sown broadcast. As Sigaut (1992: 402) observed, the only advantage of sowing in rows is a saving on seed grain. The method of broadcast sowing seems primitive, however, it is actually a more advanced technique, which is only used in communities where the price of labour is relatively high.

It is not certain whether cereal fields were weeded. The yields in Butser Farm were obtained in fields that were usually weeded three times (Reynolds 1987b); this will be assumed for the Iron Age and Roman Period too. Weeding can be done more efficiently in fields that have been planted in rows. Weeds in the spaces between the rows can be eradicated rapidly. However, sowing in rows will also create more favourable light conditions for weeds than broadcast sowing. The time necessary for weeding is unknown. Weeding will probably not have been a limiting factor, since this could be spread over a relatively large time-span of several months.

Harvesting is the remaining process that will be considered here. The speed of harvesting is strongly influenced by the tools available. Steensberg (1979) assessed harvesting times required with different types of sickles. With modern, balanced sickles, 1000 m² could be harvested in 10 hours, which corresponds to 100 hours or 10 working days for one ha. With bronze sickles, ca. 500 m² could be harvested in 10 hours, or 20 working days for one ha. With flint sickles, ca. 400 m² was harvested in 10 hours, or 25 working days for one ha. Steensberg further cited Columella, who reported that harvesting 2500 m² of barley and 1600 m² of wheat with iron sickles required one working day (of unknown length). One ha of wheat would require six working days. Since harvesting was done by picking ears, as shown in 6.4.3, the experiments by Steensberg are of limited relevance.

Reynolds (1981a) stated that hand-picking was far more efficient than harvesting with flint sickles. Harvesting 2.5 ha could probably have been achieved within one month by one person. The data provided by Columella suggest that 15 working days might have been appropriate⁴.

In conclusion, the maximum of 3 ha of arable land needed during the Iron Age can have been sown well within one month by a single person. Another 10 days will have been required for ploughing. If a conservative harvesting speed of 20 working days per ha is assumed, it would require about one month's labour for two persons. If instead the harvesting speed indicated by Columella is assumed, 15 working days are required to harvest this area. In view of the data provided by Steensberg for modern sickles (10 days per ha), Columella's data will not be used here as they may be too optimistic. Hand-picking of 2.5 ha may be estimated to have taken ca. one month for two persons. It can be concluded that harvesting produced the greatest bottle neck as far as available time is concerned.

These calculations may be compared to the situation in the Celtic fields. These are the Iron Age arable soils found on Pleistocene soils. The fields measure 30 × 30 m. It is assumed that the size of a Celtic field was chosen so that one field could be ploughed, sown and harvested in one day (Reynolds pers. comm). Harvesting of 0.09 ha in that case would last one day, corresponding to 2.7 ha in one month. This is within the range of the 2.5-3 ha in one month assumed above.

It is worth noting that this amount of labour is required for inhabitants of a site on Voorne-Putten where pastoral farming was an important element. This observation is of great interest in view of the Early Iron Age economy. If the inhabitants of the excavated farms did not grow their own cereals, they had to obtain them from inhabitants of the levees. However, these inhabitants also had to harvest cereals for their own consumption. If the inhabitants of the peaty area were specialized cattle breeders, the amount of cereal calories required by the inhabitants of the levees will have been higher. In consequence, they had to invest considerably more than one month for two persons in harvesting. In view of the small family sizes and the fact that harvesting was not the only task, these inhabitants would probably not have time to harvest cereals for their own demands and the extra amount required by the peat dwellers.

Gregg (1988: 161-162) assumed that sowing was the bottle-neck during Neolithic times. She pointed to the possibility that hunter/gatherers probably aided farmers in return for part of the yield. This mutualistic behaviour, according to her, is more favourable than competition, which is

“detrimental to interacting populations, [while] a mutualistic relationship is beneficial to both”.

The same might apply to the relationship between Iron Age inhabitants of the levees and the peat, especially for harvesting. However, the difference with purely autarkic peat inhabitants that cultivated crops on the levees themselves, becomes very small, at least from an archaeological or palaeobotanical point of view. In conclusion, the inhabitants of the peaty area during the Iron Age lived in the grey zone between exchange and aid in harvesting, and own crop cultivation at a considerable distance.

For the Roman Period, 14.3-17 ha of grain was to be sown in rows and harvested to fill the a granary. If the time estimated above is correct, planting in rows would have cost 57-68 working days. Two people would probably not manage planting within one month. With a drilling ard, the amount of labour could be reduced to 18-22 days. Broadcast sowing would save even more time. This, however, will certainly have lowered the yield ratio. If a yield ratio of 1:4 is assumed for broadcast sowing of 200 kg/ha, 7.5-8.9 ha had to be sown to fill a granary with walls. However, the amount of grain to be saved for sowing the next year would amount to 1500-1780 kg. The potential overproduction of 5400 kg of grain (see 6.6.3.2) is considerably reduced. Not sixteen, but eleven soldiers could have been provided with grain for one year.

For harvesting the 14.3-17 ha of grain planted in rows, 286-340 working days may have been required (20 days per ha). This would necessitate seven to eleven persons, while a farm probably was inhabited by six or eight, of which five or six at a maximum could have been involved efficiently with harvesting. There is a probability that a granary was used by more than one household. However, in that case the surplus production would be considerably reduced. It is far more probable that broadcast sowing was practiced to save labour.

In the case of broadcast sown grain, harvesting the 7.5-8.9 ha would still need 150-180 working days. This is at the upper limit of the feasibility for the inhabitants of one farm, as five to six harvesters would be needed. A higher yield ratio would lower the area to be harvested. However, in broadcast sowing, a yield ratio of more than 1:4 may be unrealistic (see also Sigaut 1992: 403).

The considerable difference between broadcast sowing and planting in rows has much less effect for the Iron Age situation. The area sown during the Iron Age was much smaller, and therefore also the amount of grain to be saved for sowing the next year would be smaller. The acceptance of broadcast sowing during the Roman Period would imply that the area available for arable farming around the Bernisse was a less limiting factor than in the case of planting or rows, since for each farm 17.8 ha at maximum would be needed instead of 29-34 ha (compare 6.6.3.1). It can be questioned whether the sowing method will leave any traces

in an archaeological context. The rake found in the Roman settlement of Nieuwenhoorn (cf. Van Trierum *et al.* 1988) may have served to cover the seeds after broadcast sowing. Significantly, Zimmermann (1984: 257) stated that the first rakes in northern Germany and the Netherlands are also of Roman age. This implement may have had other functions as well (e.g. hay-making), but raking of broadcast sown grain (first necessary during the Roman Period) is an appealing function.

In conclusion, the native Roman farms had the storage capacity, the area of land and the amount of labour to produce an amount of grain per farm, which was appropriate to feed ca. eleven soldiers. The production of this large amount of grain will have posed a considerable time stress upon the inhabitants.

6.7 The influence of the Roman occupation

6.7.1 INTRODUCTION

To be able to assess the influence of the Roman occupation of Voorne-Putten, it is first necessary to know the situation before the Roman occupation. In the previous paragraphs, an attempt was made to reconstruct the economy of the Iron Age sites, which were single farmsteads. A picture of regional or even local autarky seems the most probable on the basis of the investigations of botanical macroremains, pollen and wood. The absence of granaries near the Iron Age settlements on Voorne-Putten and their presence in coastal sites on mineral soils (Van Heeringen 1992: 313-318) may indicate that the emphasis lies on pastoral farming in the former and on arable farming in the latter environment. Apparently, the subsistence economy was not necessarily uniform, but rather differed with the environmental setting.

This picture closely resembles to the reconstructions of Roymans (1983) of the North Belgic tribes in the Late Iron Age. This area lies immediately south of Voorne-Putten. According to him (1983: 52),

"the economy is poorly integrated but rather characterized by a large degree of local and regional autarky. All traces are lacking of centralization and storage of tribute flows in regional and supra-regional centres. More or less urbanized oppida are unknown in the North Belgic area".

According to Roymans (1983: 53), there were hardly any contacts with the Roman world during the final part of the Late Iron Age. Besides,

"the infrastructure appears to be less developed in the area of the North Belgic tribes. Caesar frequently mentions almost impassable roads and hardly accessible forests and swamps. Bridges over larger rivers are not mentioned. This all indicates that the information and communication network was simple and weakly developed".

Slofstra (1983) also stressed the poor infrastructure of northern Gallia Belgica at the start of the Roman occupation.

In the same volume, Groenman-van Waateringe (1983)

reviews the drastic modification of the economy of natives in the Dutch East Indies and in East Africa after the advent of colonialism, as a reference for the situation during the expansion of the Roman Empire. These modifications are:

1. the native agricultural systems are disrupted in favour of production for an overseas market.
2. there is a move away from a small-scale mixed economy to large-scale monocultures.
3. the existing market and exchange patterns are dismantled, partly in order to exercise increased control.
4. a trading network is transferred into a taxation network.

Groenman-van Waateringe (1989: 101) distinguished three periods in the provision of food for the Roman army by the native people on the northwestern fringes of the Roman Empire. The first was during the campaigns, when the Roman army had to keep its supply lines continually in mind. The quality and quantity of food produced by the natives did not meet the army's demands. The Roman army is thought to have mainly requested wheat, whereas the Late Iron Age farmers, according to her, mainly cultivated barley on the poor Pleistocene sands and the more or less saline coastal areas. Davies (1971: 140) in this respect stated that barley was normally given to soldiers as a punishment.

The second period she distinguished was during the early phase of occupation, from the middle of the first to the early second centuries AD. In this period, because of the qualitative and quantitative differences between the Roman demands and the local production,

"something entirely new had to be constructed and that took time".

During this period, the Roman soldiers were forced to cultivate the military land around the forts themselves. Only during the second to the third centuries was a local food supply guaranteed according to Groenman-van Waateringe. This is also the period in which the large agrarian buildings in Roman style (*villae*) flourished.

According to Davies (1971), a major source of food for the Roman army in peace-time was provided by civilians of the provinces; this could take the form of requisitions or compulsory purchases at a fixed price.

The third period was towards the end of the Roman occupation in the second half of the third century and the fourth century. In this period, arable farming would have become less attractive to the native population because of soil exhaustion and erosion caused by over-exploitation on the poorer soils. Besides, the more fertile soils best suited for wheat cultivation were adversely affected by changes in the water level in marine, perimarine and riverine areas. As a result, grain had to be imported from Britain by ship, as is attested by historical sources.

In the light of all this, it is interesting to examine the results produced by the Roman sites on Voorne-Putten. This will be carried out in the following paragraphs.

6.7.2 NIEUWENHOORN 09-89: A NATIVE ROMAN SETTLEMENT DURING THE EARLY PHASE OF THE ROMAN OCCUPATION

The four subsequent farms on this site could be dated by means of dendrochronology (see 3.1.6). The phases started at 57 AD, 63 AD, 84 AD and 107 AD respectively, precisely corresponding to Groenman-van Waateringe's phase 2 (see 6.7.1). She called this a period of change from subsistence production, mainly of barley, to a surplus production of wheat.

It is tempting to suggest that the absence of a granary on this site may indicate a still relatively small-scale grain production. Unfortunately, such a structure may well have been missed, since the excavation trench stopped just outside the house walls.

The crop plant remains of Nieuwenhoorn are dominated by barley, while emmer occurs rather scarcely. At first sight, the spectrum of crop plants seems to plead against an arable overproduction for the Roman occupants, as this seems to require wheat.

Interestingly, Groenman-van Waateringe and Pals (1983) described similar abundant occurrences of barley in the native Roman farmsteads in Assendelft, where again emmer occurred scarcely. Palynological investigations on these same sites, however, did yield dominant *Triticum* pollen grains. Groenman-van Waateringe (1989: 100) interpreted these data by assuming that wheat (*Triticum*) was produced, but only to export it to the Roman army. Barley was kept for own consumption. The fact that, according to Groenman-van Waateringe, barley is the dominant crop in the Late Iron Age fits in with this hypothesis. The export of wheat may have occurred in Nieuwenhoorn too.

Some observations, however, plead against this hypothesis. Firstly, large amounts of grain for the Roman army seem to have been transported and stored as completely cleaned grain. If all crop processing is indeed conducted on the site of production, this would leave glume remains of wheat on the site.

Secondly, Groenman-van Waateringe and Pals (1983: 154) reported the regular occurrence of *Triticum*-pollen in the Iron Age site of Assendelft site Q, where emmer grains and spikelet forks were scarce. *Hordeum* pollen was absent on site Q, but numerous barley grains and internodes were found. Export of wheat from this site, where emmer is thought to have been imported (cf. Therikorn *et al.* 1984: 368) seems out of the question. One might question the certain identification of *Triticum* pollen grains, but the elaborate documentation by Groenman-van Waateringe and Pals (1983: 144-146) makes it rather undisputable. In conclusion, the occurrence of *Triticum* pollen grains on a site apparently may not coincide with its local cultivation. Redeposition could be an explanation, but has been excluded by Groenman-van Waateringe and Pals.

Besides, in an environment which can be considered unsuited to the cultivation of wheat, such as the peaty environment of Nieuwenhoorn, barley could have been grown for the Roman army. In view of the regular occurrence of barley in Roman castella (Neuß: Knörzer 1970; Valkenburg: Van Zeist 1970) the avoidance of barley for human consumption may have been not as strong as Davies and Groenman-van Waateringe suggested.

Pals *et al.* (1989: 129) in this respect concluded that

"the Roman influence in the Netherlands was not characterized by a shift from barley to wheat, but merely by a diversification in cereal types".

Furthermore, not the soldiers, but their horses may have been the main consumers of barley. The large farms in Nieuwenhoorn point towards a greater role for stockbreeding on these farms as compared to those in Rockanje and Simonshaven. The considerably higher share of grassland plants in Nieuwenhoorn as compared with Rockanje (see table 30) also indicates a greater importance of stockbreeding in the former settlement. Animal products could have served as payment of the Roman tributes as well. Since the botanical information mainly concerns the first two building phases, it may also be possible that the economy had not yet changed to the production of a surplus.

6.7.3 ROCKANJE II: A NATIVE ROMAN SETTLEMENT DURING THE CONSOLIDATION PHASE OF THE ROMAN OCCUPATION

This site dates from the second half of the second and the first half of the third century AD. It is the period in which, according to Groenman-van Waateringe, the local food supply for the Roman army was more or less guaranteed. The native economy had changed into an economy involving surplus production.

Most remarkably, the botanical macroremains of Rockanje did reveal hardly any trace of wheat, barley is practically the only crop attested. The fact that the settlements are located in a salt marsh environment explains the virtual absence of wheat, at least among cereals cultivated locally. Furthermore, the farms in Rockanje were much smaller than those in Nieuwenhoorn. If we interpret this as evidence for a subordinate role of stockbreeding, what was exported to meet the Roman demands? Several options can be put forward. Firstly, salt making may have been an important economic activity for the inhabitants of Rockanje. In the Late Iron Age site of Rockanje pottery, which is related to salt production is of considerable importance (Van Trierum *in press*). However, this pottery has not been found in the Roman site of Rockanje (Hallewas *pers. comm.*).

Secondly, barley may have been produced in surplus, which is corroborated by the large granary on this site. The

Roman army may have used barley for its own consumption (see 6.7.2) or for feeding its horses. The fact that in the Dutch castella cavalries played an important role (Willems 1986), demonstrates the need for food for horses.

Thirdly, the farmers may have been horse breeders themselves. According to Thirsk (1965), a salt marsh provides excellent pasture for horses as well as for sheep. The surplus of barley produced could have served as winter food for these horses as well as serving as food for the humans. Two of the excavated houses in Rockanje are of such a size, that part of them could have served for housing livestock. Besides, it cannot be excluded that horses were kept outside in winter, so large farms with byres were probably not necessary.

In conclusion, the influence of the Roman occupation of Voorne-Putten is not clearly expressed. Only the appearance of large granaries and the diversification of house plans indicate that economic conditions did change quantitatively. Qualitative changes cannot be demonstrated. The fact that the investigated site of Rockanje may have been located close to a military settlement near Oostvoorne (see 1.2) is apparently of no influence.

6.8 Summary

In the small Iron Age farms on Voorne-Putten, with six stalls, livestock provided most or all of the proteins required by the inhabitants. If the farm was inhabited by four persons, ca. 47-67% of the yearly energy requirements was provided by animal products, in case of six inhabitants plus a baby, this figure corresponds to 31-44%. The remaining calories will have been provided by crops. Cereals will have constituted the main suppliers of vegetable calories, mainly in the form of carbohydrates. To supply the remaining calories, the four inhabitants needed 300-455 kg of grain per year, the six inhabitants plus a baby 850-1030 kg. These amounts of grain could have been grown on 1-3 ha if moderate yields are assumed.

In larger farms, with ten stalls, the protein requirements of six inhabitants will largely have been provided by animal products. The calories provided will have covered 58-84% of the needs of four inhabitants and 38-54% for six inhabitants and a baby. The grain needed to supplement the energy is 150-394 kg and 665-910 kg per year respectively. This amount can be obtained from 1-2.5 ha, assuming moderate yields.

One month of labour may be conceived as the maximum possible time for sowing and one month for harvesting the cereals. The time required to sow and harvest 1-3 ha is well below one month of labour for two persons. The land required will have been ca. 13-22 ha for the domesticated animals. This land could be found in the immediate surroundings of the site. If allowance is made for a fallow every year, 5 ha of arable land is the maximum requirement for

one farm. The levees along the Meuse provided enough arable land for dozens of Iron Age farms. This is much more than the probable number of synchronous farms, which in the peaty area may not have exceeded six (during the Middle Iron Age).

The point that can be raised against autarkic production of agricultural products is the 3-4 km distance between the levees along the Meuse and the Iron Age settlements. However, Chisholm (1968: 48) stated that

"the average distance to the cultivated land is commonly of the order of one kilometre or more and very frequently rises to three or four".

The alternative is that the inhabitants of the farms in the peaty area imported their cereals. An exchange of cereals for animal products during the Iron Age has been suggested by Van Gijn and Waterbolk (1984) and by Brandt and Van Gijn (1986). However, the amount of labour required to harvest cereals by any inhabitants of the levees for their own demands as well as for trade is too large to be feasible. They would have needed the assistance of the peat dwellers for harvesting and probably also for sowing. The difference between exchange and aid versus production by the peat inhabitants themselves is thus small, that it most probably cannot be traced archaeologically. Anyhow, at least on a microregional level, the society was autarkic.

The situation during the Late Iron Age was more favourable for arable farming, due to the Dunkirk I sediments that were deposited prior to the Late Iron Age. The settlements are located in the vicinity of or directly upon these clayey sediments. An autarkic subsistence economy is not hampered by the distance of the arable fields away from the homesteads.

The situation during the Roman Period differs in that a surplus production of agricultural products for the Roman army must be considered. The large farms in Nieuwenhoorn suggest a comparatively large importance of stockbreeding. It is assumed that livestock was equivalent to that in an Iron Age farm with ten stalls.

The amount of proteins provided by animal products will more or less have been sufficient for the needs of six inhabitants plus a baby. The energy requirements will have been covered for 38-54% by animal products. In cases of eight inhabitants, animal products will have covered 52-76% of the demands for protein and 25-36% for calories.

Granaries have been demonstrated near two of the three excavated Roman settlements on Voorne-Putten. The absence of a granary near Nieuwenhoorn is not conclusive, since the trenches hardly reached beyond the house walls on this site. The storage capacity of the granaries is large enough to store a surplus of ca. 5400 kg of grain.

The area of arable land required to grow this surplus of grain and to feed livestock will have been sufficient on

Voorne. Around the Bernisse, the carrying capacity of the area for crop raising was probably exceeded. If sowing was in rows, 16-22 ha would be required to produce this surplus. This could not have been harvested within one month by the inhabitants. If sowing was broadcast, 7.5-8.9 ha would be required if the yield amounted to 1:4. This is at the upper limit of the feasibility for the inhabitants. In this case, a larger part of the surplus must be reserved for sowing the next year. The remaining surplus of 3645-3900 kg could feed at least eleven Roman soldiers. The harvest will have been a period of enormous time stress for the family that had to produce this surplus.

The local inhabitants on Voorne-Putten had enough land to produce a surplus for the Roman army, the labour requirement may have been appropriate to reach a surplus production to feed at least eleven soldiers.

notes

1 In *A. fatua*, the glumes of the two grains in one spikelet both have awns, while in *A. sativa* only the lower grain may have an awn (cf. Körber-Grohne/ Bickelmann/ Leist 1988).

2 The recovery of samples of grain without chaff does pose some additional problems, as is clearly illustrated by Behre (1990b). He described a sample from Iron Age Rullstorf, which mainly consisted of carbonized naked *Avena* spec. grains (95.2%). The sample had been sieved on the site during the excavation. Kroll also took a sample on this site and sieved it himself. He found 99% *Avena sativa* in its chaff. Apparently, the carbonized seeds were "threshed" by sieving in Behre's material!

3 "Find-units" are pottery sherds, wooden posts and other artefacts (each specimen counting as one). The presence of dung also counts as one find-unit.

4 Gregg (1988: 161) stated that the figures provided by Steensberg (1979) suggest a harvesting time of 32.1 hours for harvesting one ha of wheat with flint sickles. However, Steensberg's data (cf. his table 12) yield figures of ca. 250-333 hours per ha (10,000 m²) for flint sickles. On the basis of her erroneous calculations, Gregg concluded that the time needed for harvesting was no bottle-neck at all. Gross *et al.* (1990: 95), who based themselves on Gregg's publication, came to the same conclusion for Neolithic farmers.

Identification criteria of botanical macroremains occurring in the investigated sites

An exhaustive description of all the taxa encountered is not considered useful at the present state of palaeo-ethnobotanical research. In the past, many taxa from a great number of sites have been recorded and described by many authors. When palaeo-ethnobotany was still in its infancy, this proved very useful. Nowadays, however, it may be assumed that common species do not present identification problems, largely because of the thorough descriptions published earlier. Of course, the taxa included below represent a personal choice of the available material, based on the number of already existing descriptions known to me.

The material is stored in the palaeo-ethnobotanical laboratory of the *Instituut voor Prehistorie, Rijksuniversiteit Leiden*, and this material is available for examination.

The taxa are grouped per family, different families are treated alphabetically, as are the species per family. Measurements have an accuracy of 0.03 mm, except for seeds and fruits exceeding 3.6 mm, in which case the unit of measurement is 0.06 mm. Unless otherwise stated, measurements and descriptions concern waterlogged (uncarbonized) material.

Alismataceae

Sagittaria sagittifolia

Sp.17-35:598 (n = 1): 2.22×1.25 mm.

As far as I know (and this applies to all following descriptions), the embryo of *Sagittaria* has only been described by Wieserowa (1979: 146). Its U-shape (see fig. 64) is strongly reminiscent of the embryo of *Alisma plantago-aquatica*. The size, however, is larger, whereas this never exceeds 1.8 mm in *Alisma*. The size and shape of the *Sagittaria* embryo correspond closely to Wieserowa's description (2.4×1.3 mm) and to recent ones in our reference collection.

Callitricheaceae

Callitriche spec.

Sp.17-34:266 (n = 25): $1.18 (1.09-1.31) \times 0.61 (0.48-0.70)$ mm.

The fruits of the *Callitriche* species offer the most reliable criteria in identifying recent species. Some are clearly winged, others are not. The preservation of the material in

the samples containing *Callitriche* fruits is excellent without exception. The present fruits are clearly unwinged. *Callitriche obtusangula* is the only unwinged species, whereas the more common species *Callitriche platycarpa* has a small wing. It is, however, not clear whether the absence of the wing is an original feature in the subfossil material or whether it is caused by (unobserved) corrosion. The fruits have therefore not been attributed to a species.

Caprifoliaceae

Sambucus cf. *nigra*

Sp.17-35:598 (n = 1): 3.32×1.68 mm.

The seeds of *Sambucus nigra* are larger than those of *S. racemosa* and *S. ebulus* (cf. Knörzer 1970). However, Fredskild (1978) showed that there is a considerable overlap between these species, *S. ebulus* measuring up to 3.7 mm and *S. racemosa* up to 4.1 mm, while in *S. nigra* the length ranges from 2.7 to 4.7 mm. The width ranges also largely overlap, *S. ebulus*, however, is too wide for the present seed. Since the seed from Spijkenisse does not exceed the sizes of *S. racemosa*, it is presented only with reservation. The commonness of *S. nigra* and the present-day absence of *S. racemosa* in the Holocene part of the Netherlands are circumstantial evidence pointing to *Sambucus nigra*.

Caryophyllaceae

For the measurements of Caryophyllaceae, the length of the seeds is taken as the largest diameter and the width as the diameter perpendicular to it.

Arenaria serpyllifolia ssp. *macrocarpa*

Nh.09-89:3039 (n = 1): 0.75×0.59 mm

The kidney-shaped seeds have blunt warts, in contrast to the similar small seeds of *Lychnis flos-cuculi*. The size normally reported for this species is up to 0.6 mm (cf. Körber-Grohne 1967; Knörzer 1967, 1970, 1973, 1975, 1981; Van Zeist 1974; Körber-Grohne/ Wilmanns 1977; Wasylikowa 1978; Wieserowa 1979; Pals 1987; Jacquat 1988; Jacomet *et al.* 1989). Only Dickson *et al.* (1970: 58) mention seeds ranging from 0.65 to 0.8 mm. They are attributed to ssp. *macrocarpa*, which occurs near the British coasts. Van der Meijden

et al. (1983) also mention this subspecies from coastal dunes in the Netherlands. The seeds of one specimen of this subspecies in our reference collection from the dune area near The Hague (the Netherlands, from *Rijksherbarium*, Leiden) measured $0.63 (0.58-0.69) \times 0.50 (0.43-0.54)$ mm ($n = 10$). This size range thus shows an overlap with ssp. *serpyllifolia*. The taxonomic value of the two subspecies is at present being examined at the *Rijksherbarium* (F. Adema pers. comm.) and is beyond the scope of the present publication.

Moehringia trinervia

Sp.17-35:600 ($n = 26$): $1.11 (0.90-1.21) \times 0.88 (0.74-0.98)$ mm.

The average size and the range of this sample are practically identical to the recent data mentioned by Knörzer (1971a). Furthermore, the lustrous, smooth seeds with faint, radial grooves on the edge are clearly different from all other Caryophyllaceae.

Stellaria aquatica and *Stellaria media*

Stellaria aquatica seeds resemble those of *Stellaria media*, although on average they are somewhat smaller. The criterion given by Wieserowa (1979) and Jacomet (1986) proved very useful in case of doubt; *Stellaria media* has small spines superimposed on the warts, the warts of *Stellaria aquatica* are bare.

Sagina species.

The very small seeds of *Sagina* were mostly found on the 1/4 mm sieve. According to Behre (1983), further identification of these species does not seem possible. Pals (1987), however, distinguishes a *Sagina apetalaprocumbens*-type. Its

Table 37. Sizes of *Sagina* species.

<i>Sagina apetalaprocumbens</i>	
Hortus Genève: Genève, Switzerland	0.27-0.30 mm
Hortus Glasnevin: Bunclady, Ireland	0.29-0.35 mm
Rijksherbarium: Den Haag, Netherlands	0.26-0.32 mm
Hortus Helsingborg: Helsingborg, Sweden	0.28-0.35 mm
<i>Sagina procumbens</i>	
Botanische Garten Marburg: Marburg, Germany	0.26-0.32 mm
L.U. Wageningen: Wageningen, Netherlands	0.30-0.36 mm
<i>Sagina maritima</i>	
Rijksherbarium: Schiermonnikoog, Netherlands	0.40-0.49 mm
Hortus Helsingborg: Helsingborg, Sweden	0.37-0.42 mm
<i>Sagina subulata</i>	
Rijksherbarium: Harlingen, Netherlands	0.38-0.46 mm
<i>Sagina nodosa</i>	
Hortus Oslo: Bærum, Norway	0.37-0.48 mm
Hortus Helsinki: Kotka, Finland	0.45-0.55 mm

largest diameter is ca. 0.35 mm, and therefore smaller than *S. nodosa*, *S. subulata* and *S. maritima* (see also Kulpa 1974). Measurements of ripe seeds in our reference collection have largely confirmed these observations. In table 37, the largest diameters for 10 recent specimens per sample are given. (Measuring units are 0.016 mm).

Based on these data, two taxa within subfossil *Sagina* seeds were distinguished, i.e. *Sagina apetalaprocumbens* with a largest diameter of ca. 0.35 mm and *Sagina nodosa*-type which measure at least 0.40 mm.

Sagina apetalaprocumbens

Sp.17-34:279 ($n = 11$): $0.35 (0.32-0.38) \times 0.26 (0.24-0.29)$ mm

Sp.17-35:612 ($n = 6$): $0.35 (0.34-0.38) \times 0.27 (0.24-0.30)$ mm

This type is clearly more common than *Sagina nodosa*-type and in most, if not all cases, *Sagina procumbens* will be represented, which is a very common, tread-resistant species.

Sagina nodosa-type

Sp.17-34:515 ($n = 2$): 0.48×0.36 ; 0.57×0.46 mm

Gv.17-55:2 ($n = 1$): 0.56×0.43 mm

This type was found in four samples, in two cases occurring in combination with dominant *Sagina apetalaprocumbens* seeds, in the other two cases only *Sagina nodosa*-type was present. It seems unlikely that we are dealing with extraordinary large *S. apetalaprocumbens*.

Silene vulgaris

Sp.17-34:279 ($n = 1$): 1.60×1.38 mm.

The size of these seeds is somewhat larger than in the other *Silene* (including *Melandrium*) species in our region (see also Jacomet *et al.* 1989). Furthermore, the criterion given by Knörzer (1981: 49) proved valuable, *Silene vulgaris* having 4-5 rows of warts in lateral view, the *Melandrium* species showing 7 of these rows in lateral view. This is also apparent in our reference collection.

Stellaria palustris

Div. ($n = 5$): $1.60 (1.54-1.64) \times 1.19 (1.10-1.29)$ mm

The oblong seeds have protracted warts, as in *Stellaria graminea*, which has a more rounded appearance and does not exceed 1.3 mm.

Chenopodiaceae

Atriplex littoralis-type

Div. samples ($n = 5$): $2.64 (2.54-2.85) \times 2.35 (2.02-2.66)$ mm

Nh.09-89:3035 ($n = 5$): $2.57 (2.02-3.41) \times 2.39 (1.98-3.07)$ mm

Table 38. Sizes of *Cirsium* species.

<i>C. vulgare</i>	
Eupen, Belgium: IPL, Leiden	3.66 (3.58-3.78) × 1.49 (1.41-1.60) mm
Hienheim, Germany: IPL, Leiden	3.69 (3.52-3.90) × 1.43 (1.28-1.60) mm
<i>C. oleraceum</i>	
Neustadt, Germany: IPL, Leiden	3.96 (3.46-4.29) × 1.59 (1.41-1.79) mm
Hienheim, Germany: IPL, Leiden	3.61 (3.26-3.90) × 1.52 (1.41-1.73) mm
<i>C. palustre</i>	
Helsingborg, Sweden: Bot. Garden Heslingborg	3.05 (2.69-3.26) × 1.22 (1.15-1.31) mm
München, Germany: Botanical Garden München	3.30 (3.07-3.46) × 1.29 (1.22-1.34) mm
<i>C. arvense</i>	
Heemstede, Netherlands: IPL, Leiden	3.09 (2.82-3.26) × 1.15 (1.09-1.22) mm
Amersfoort, Netherlands: IPL, Leiden	3.60 (3.20-3.84) × 1.24 (1.09-1.34) mm

For this type Van Zeist (1974) has been followed. He distinguishes this type having a largest diameter exceeding 2 mm, it includes *A. littoralis* and *A. prostrata* (*hastata*) var. *salina*. It has a distinct reticulate pattern on the surface.

Chenopodium glaucum

Rock.1-0-6 (n = 10): largest diam 0.98 (0.90-1.06) mm

Chenopodiaceae seeds without visible hilum and smaller than 1.2 mm (and with a smooth surface in contrast to unripe *Atriplex* seeds) belong to *C. glaucum* or *C. rubrum*. On the basis of our reference material it proved possible to distinguish the two species. *Chenopodium glaucum* has a circular outline and is on average larger (0.8-1.2 mm) than the elongated seeds of *Chenopodium rubrum*, which usually do not exceed 0.9 mm (see also Guinet 1959). In some cases, a few questionable seeds occurred in samples with many *Chenopodium rubrum* seeds. Only in Rockanje could *Chenopodium glaucum* be demonstrated unambiguously.

Chenopodium polyspermum

Sp.17-34:289 (n = 1): largest diam. 1.15 mm, thickness 0.61 mm

Only one seed of this species was found in the present study. It corresponds exactly to the descriptions in the literature consulted. It has a radial pattern on both sides of the seed, in contrast to *Chenopodium ficifolium*.

Salicornia europaea s.l.

Sp.17-30:309 (n = 8) 0.76 (0.68-0.86) × 0.54 (0.47-0.67) mm

According to Van der Meijden (1990), this taxon can be divided into three species, *S. disarticulata*, *S. europaea* s.s. (= *S. brachystachya*) and *S. procumbens* (= *S. dolichostachya*). The latter species has 1.0-1.7 mm long seeds compared to 0.6-1.4 mm long seeds in the first two species. Apparently, *S. procumbens* is absent in the present material. This species occurs mostly below mean sea level, while *S.*

europaea s.s. is mainly restricted to places above this level.

S. disarticulata occurs on still higher places and is very rare, which renders *S. europaea* s.s. as the most likely species in our material.

Compositae

Artemisia cf. *vulgaris*

Rock.2-0-12 (n = 18): 1.18 (1.02-1.30) × 0.48 (0.40-0.62) mm

The oblong seeds offer very few characteristics for identification in magnifications up to 50x. Fortunately, in Rockanje, one uncarbonized seed was found to be covered by numerous pollen grains, which could be identified as *Artemisia* spec. (see fig. 98). In microscopic view (ca. 100 ×), the seed surface appeared to consist of rows of slightly S-shaped cells (see fig. 99). These characteristically shaped cells could also be seen in specimens in other samples which lacked the accompanying pollen grains (see also Jacomet *et al.* 1989). In some specimens, this cell pattern was covered by long, bifurcated projections, which remind one of those found in *Juncus*.

Bidens cernua

Apart from the commonly used criterion based on the number of projections (mostly 4, while 2-3 in *B. tripartita*), the shape also proved to be a reliable criterion. As mentioned by Behre (1983: 169), *B. cernua* fruits taper toward the base, whereas *B. tripartita* has a broader base (see also Katz *et al.* 1965, fig. 4 and 5).

Cirsium species

Behre (1976c: 119) presented measurements of recent fruits of the *Cirsium* species. His measurements are based upon 20 fruits per species. In table 38, measurements of another 20 fruits from our reference collection are presented. For each species, two samples from different places were measured, 10 fruits per sample.

On the basis of both data, the length can generally be used to distinguish *C. arvense* and *C. palustre* (average less than 3.6 mm) from *C. vulgare* and *C. oleraceum* (more than 3.6 mm). The width does not seem to be a useful criterion in distinguishing the species within these two groups, in contrast to the suggestion in the data of Behre. In Behre's material, *C. vulgare* has a larger average width than *C. oleraceum*, while the reverse is true in our reference material. Behre also mentions a difference in the collar of these species. *C. vulgare* has an oblique collar, whereas it is straight in *C. oleraceum*. This is also the case in our reference material and seems a better characteristic to distinguish these species than the width.

Concerning *C. palustre* and *C. arvense*, Behre's data reveal that the width of *C. palustre* is larger. In our material they are almost equal. According to Behre, the collar of *C. palustre* is oblique, while only slightly so in *C. arvense*. Unfortunately, this is not confirmed in our reference collection. In both species the two types occur regularly, although in *C. arvense* the majority of the collars are straight. Van Zeist (1974) indicated the presence of longitudinal ribs for seeds of *C. palustre*. In the best preserved specimens this proved to be an additional characteristic of some use. In fruits in a more corroded state, however, these ribs probably cannot be seen.

Cirsium arvense-type

Sp.17-34:div.(n=2): 2.70 × 0.94 mm; 3.10 × 1.10 mm

Because of the very small width, it seems most likely that we are dealing with *C. arvense* here (see fig. 65). Apart from these seeds, seven fruits occurred in sample Sp.17-35:598 within the length range of *C. arvense/palustre*. The width ranged from 0.90-1.56 mm. It proved impossible to demonstrate a clear boundary, so in this sample no separation was made.

Cirsium palustre

Div.(n=5): 3.33 (3.13-3.68) × 1.48 (1.34-1.66) mm

Because of their longitudinal ribs, the seeds were attributed to *C. palustre*. Owing to flattening the width is probably not representative (see fig. 66).

Cirsium vulgare

Rock.10-2-56 (n=1): 3.52 × 1.92 mm.

All the larger *Cirsium* seeds found have an oblique collar, so they have been attributed to *C. vulgare* (see fig. 67).

Senecio aquaticus

Sp.17-35:612 (n=25): 1.77 (1.41-2.24) × 0.66 (0.48-0.80) mm

The attribution of seeds to this genus is based on the 10-12 faint ribs and the collar-like pappus-base (cf. Knörzer 1981). Our reference material revealed that the small size of the present fruits excludes the larger *S. congestus*, *S. fluviatilis*, *S. fuchsii*, *S. paludosus* and *S. viscosus*, while *S. sylvaticus* and *S. vulgaris* are more slender (see also Knörzer 1970). *S. erucifolius* and *S. jacobaeae* are of comparable size to *S. aquaticus*. In these species, however, the ribs are more pronounced. The present seeds correspond in detail to *S. aquaticus* only (see fig. 68).

Xanthium strumarium

Zl.17-27:8 (n=11): 11.81 (10.61-13.10) × 8.10 (7.07-9.17) mm

The fruits of *Xanthium strumarium* are highly characteristic. Their size, the hooked spines on the surface and the two apical points are of great diagnostic value (see fig. 69).

Convolvulaceae

Calystegia sepium

Ro.08-52 (n=1): 5.0 × 4.1 mm

The large seeds have a conspicuous, more or less triangular hilum (Knörzer 1970). The surface of *Calystegia* is smooth, in contrast to the warty surface of *Convolvulus arvensis* (see fig. 70). *Calystegia soldanella* has even larger seeds than *C. sepium* (see also Frank/Stika 1988).

Cruciferae

Brassica rapa (= *B. campestris*)

Sp.17-30:126 (n=21): largest diameter 1.85 (1.54-2.30) mm

More or less globular Cruciferae-seeds belong to *Brassica*, *Raphanus* or *Sinapis*. *Raphanus*-seeds are in general larger than *Brassica* and *Sinapis* and the seed wall shows a distinct reticulum. *Sinapis*-seeds have a fainter reticulum than seeds of *Brassica* (cf. Van Zeist et al. 1987).

The identification of *Brassica* seeds posed great difficulties to many authors. Wieserowa (1979) identified all four species (*B. rapa*, *B. napus*, *B. nigra* and *B. oleracea*) from Polish cesspits. The criteria she mentions (which apparently have been overlooked in a range of later publications) were tested on recent material. The shape of the meshes on the seed coat were studied with the use of a Leitz-microscope with incident light, at a magnification of 100x. To avoid incorrect identifications the recent seeds were collected from specimens of the *Rijksherbarium* in Leiden. Dr. R. van der Meijden checked the identifications and subsequently seeds of the clearest examples of each species were sampled. The criteria of Wieserowa allowed to distinguish three of the four species. *Brassica rapa* (= *B. campestris*) has a reticulum with polygonal meshes (honeycomb-shaped). Around the hilum

Table 39. Sizes of *Cochlearia* species.

<i>C. danica</i> Amsterdam, Netherlands: Hortus Vrije Universiteit	1.08 (1.02-1.24) × 0.91 (0.80-0.99) mm
<i>C. officinalis</i> Frankfurt, Germany: Botanical Garden	1.44 (1.27-1.55) × 0.95 (0.90-1.21) mm
<i>C. anglica</i> Schiermonnikoog, Netherlands: Rijksherbarium Leiden	1.75 (1.67-1.86) × 1.28 (1.18-1.40) mm

the meshes become more elongated and less clearly visible. In *Brassica nigra*, polygonal meshes are also present, but they do not change towards the hilum. The reticulum is more conspicuous than in *B. rapa* (see Berggren 1981: 126-127). A very clear, subfossil example of *Brassica nigra* has been published by Vermeeren (1990: 146), although the identification at that time was *Brassica rapa/nigra*. *B. oleracea* has elongated meshes all over the surface. *B. napus* according to Wieserowa has a very indistinct reticulum of subrectangular meshes. However, this was more variable in our material. In some cases, the reticulum was completely absent (even at a magnification of 250x). However, if present, the reticulum did consist of subrectangular meshes all over the surface, thus resembling the reticulum of *B. oleracea*. Our observations concerning *B. napus* more or less parallel the description by Berggren (1981) concerning the meshes. Körber-Grohne's (1967) observation of *B. napus* seeds with polygonal meshes becoming elongated towards the hilum must be due to hybridization with *B. rapa* or misidentification of the material. The sizes Wieserowa mentions seem less reliable, if our reference material is followed.

In view of Wieserowa's criteria (excepting size), the subfossil material from Voorne-Putten could clearly be attributed to *Brassica rapa*, if the area around the hilum was present. If this was absent, the reticulum always was reminiscent of this species, so no other *Brassica* species is present (see fig. 71).

Cochlearia officinalis

Rock.08-52:1076 (n=1): 1.40 × 1.00 mm

Cochlearia seeds have very conspicuous papillae. The published sizes of the seeds of the three species are somewhat confusing. According to Berggren (1981), *Cochlearia danica* has smaller seeds (average 1.1 × 0.8 mm) than *C. officinalis* and *C. anglica* (both ca. 1.5 × 1.0 mm). Behre (1976c) stated that *C. anglica* has larger seeds (ca. 1.8 mm long), while he reports that *C. danica* differs from *C. officinalis* in the arrangement of the papillae, but he does not mention a difference in size.

Measurements of specimens in our reference collection revealed averages and ranges as shown in table 39 (n=10).

The ranges for *C. danica* and *C. officinalis* were supported by two resp. three other specimens. The sizes, apparently, can be used to separate these species. Besides, *C. danica*

shows coarser papillae than the other two species. Figure 72 depicts the subfossil specimen.

Erysimum cheiranthoides

Rock.1-0-6 (n=25): 1.62 (1.41-1.82) × 0.91 (0.80-1.09) mm

In Rockanje two samples with large numbers of a cruciferous species were analysed. The seeds have a pointed radicle and small, blunt papillae. They show a close similarity with recent *Erysimum cheiranthoides* seeds. Van Zeist (1974) is the only author who described these seeds, he reported a comparable size-range. According to him, the papillae are spine-like. However, on examination with a transmitted light microscope, the recent seeds show blunt papillae, as do the subfossil ones (see fig. 74).

Lepidium ruderae

Rock.10-2-58 (n=4): 1.06 (0.91-1.23) × 0.66 (0.53-0.75) mm

The seeds of this species are small and resemble those of *Capsella bursa-pastoris*. In contrast to the latter species, the radicle is as wide as the cotyledons and both point upwards (see fig. 73). In *Capsella*, the tip of the radicle curves above the cotyledons. The seed drawn by Körber-Grohne (1967) as *Lepidium ruderae* in my opinion belongs to *Capsella*. Other finds of *Lepidium ruderae* are unknown to me.

cf. *Sinapis arvensis*

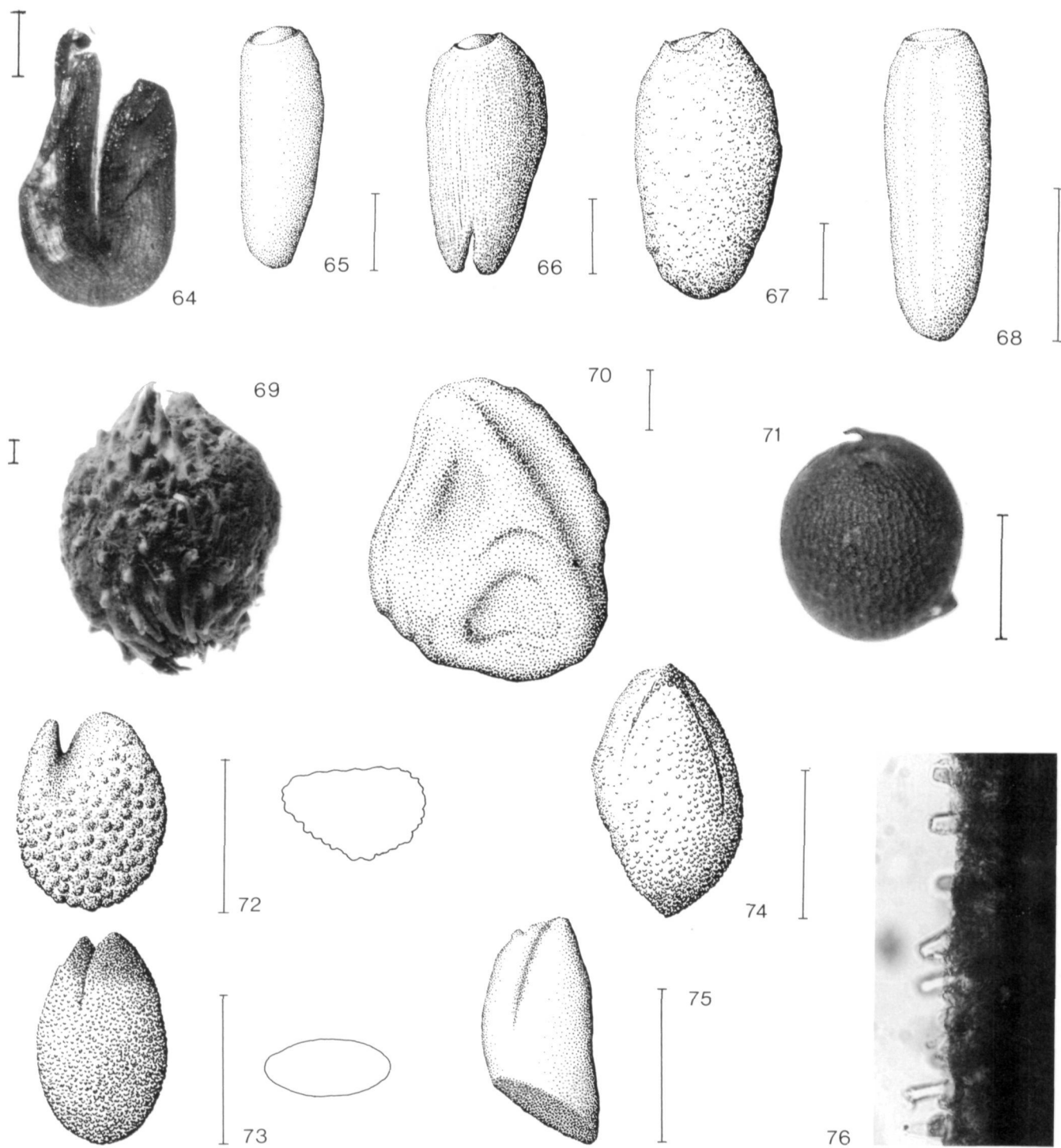
Zl.16-15:1 (n=1): 1.35 × 1.20 mm.

In this sample, one and a half mineralized, globular, cruciferous seeds were found. The reticulate surface pattern is as small as in *Sinapis*. Since the seeds are mineralized, it is uncertain whether this reticulum concerns the same cells as those that can be seen in recent material, only a tentative identification was therefore possible.

Sisymbrium officinale

Rock.1-0-6 (n=4): 1.54 (1.44-1.65) × 0.74 (0.63-0.81) mm
Sp.17-35:612 (n=25): 1.47 (1.22-1.89) × 0.99 (0.74-1.12) mm

The seeds of this species do not have papillae, in contrast to *Erysimum*. The cells are arranged in longitudinal rows. The truncated base and apex are characteristic (see fig. 75).



This is caused by the neighbouring seeds in the pods (cf. Kroll 1987). Seeds with more room are less truncate, resulting in a great variation of shape (cf. Kulpa 1974). Seeds of *Cardamine pratensis* are also angular in shape, but are not obliquely truncated.

Cuscutaceae

Cuscuta epilinum

Sp.17-34:311 (n=1): 1.82 × 1.54 mm

Nh.09-89:3001 (n=1): 1.50 × 1.10 mm

The seeds of *Cuscuta* species show faint ridges and have a rough, sponge-like surface. The different species can be distinguished on the basis of their largest diameter (cf. Van Oostroom 1942). *C. europaea* and *C. epithymum* measure around 1 mm, *C. lupuliformis* 2.5-3 mm and *C. epilinum* 1.5-1.75 mm. According to Pals and Van Dierendonck (1988), *C. campestris* has the same size as *C. epilinum*, but it lacks the rough surface. Consequently, the present specimens belong to *Cuscuta epilinum*.

Cyperaceae

Carex

The identification of sedge nutlets is generally considered to be very difficult, not in the least because often only the nutlets (called seeds hereafter) and not the more characteristic utricles (perigynia) are recovered. Therefore, often only a group of species or tentative ("cf.") identifications can be reached. Jacomet *et al.* (1989: 317) published a diagram with lengths and widths of central European *Carex* species, which is very useful for a first selection.

All measurements of Cyperaceae exclude the beak.

Carex acuta-type

Sp.17-35:600 (n=32): 2.02 (1.68-2.34) × 1.59 (1.17-1.87)

mm

Sp.17-34:337 (n=4): 1.72 (1.50-1.86) × 1.25 (1.18-1.31) mm

This type has flat seeds characterized by a broad base and distinct epidermis cells (cf. Van Zeist 1974); it includes *C. acuta*, *C. elata* (= *C. hudsonii*), *C. nigra* and *C. trinervis*. The shape is obovate to almost sphaerical. Pals (1987) discusses in detail the different species belonging to this type. He concludes that his material most closely resembles *C.*

nigra, but recent material shows considerable overlap between the species. In the present study, a large range of forms and sizes was found in one sample (Sp.17-35:600), it proved impossible to distinguish distinct types, so it was decided to lump them all together as *Carex acuta*-type (see fig. 77).

Carex acutiformis

Sp.17-35:598 (n=5): 2.02 (1.92-2.08) × 1.24 (1.09-1.34) mm

Sp.17-35:600 (n=3): 1.79 (1.60-2.10) × 1.12 (0.97-1.29) mm

The seeds are triangular. The greatest width lies in the middle, which results in a more or less elliptic outline (see fig. 78). The shape closely resembles that of *C. rostrata*. The latter species, in our reference collection, has a remarkably light colour. This is also apparent in subfossil material. Berggren (1969) mentions the great difference in colour in recent material as well (p.46). *C. rostrata* is also somewhat smaller than *C. acutiformis* (cf. Berggren 1969). *C. vesicaria* is often reported in one and the same breath with *C. rostrata*. According to Berggren, however, *C. vesicaria* has somewhat larger and wider seeds measuring 2.1 × 1.4 mm on average. This is also apparent in our reference collection. Its colour is still lighter than *C. rostrata*.

Carex cuprina-type (= *C. otrubae*-type)

Sp.17-30:123 (n=16): 2.25 (2.11-2.43) × 1.60 (1.44-1.76) mm

Sp.17-34:311 (n=3): 2.31 (2.24-2.43) × 1.40 (1.22-1.50) mm

Sp.17-35:598 (n=5): 2.20 (2.08-2.37) × 1.62 (1.50-1.82) mm

This type has broadly ovate to slightly pear-shaped seeds and the surface has a wart-like appearance when examined at a magnification of 200x (see fig. 79). According to Berggren (1969), *C. cuprina* has epidermis cells of 25-30 µm in diameter, while those of *C. vulpina* are 40-50 µm in diameter. In our reference material (which was correctly identified according to the nervation of the utricles), there was no difference in the sizes of the epidermis cells between *C. cuprina* and *C. vulpina*. More or less complete utricles were not found in the present study, so the highly diagnostic criterion of difference in the nervation on the two sides of *C. vulpina* utricles could not be used. Since *Carex cuprina* is by far the more common species in the Netherlands, the type was named after this species here.

Fig. 64 *Sagittaria sagittifolia* (12x). Sp.17-35:598.

Fig. 65 *Cirsium arvense* (12x). Sp.17-34:337.

Fig. 66 *Cirsium palustre* (12x). Sp.17-34:279.

Fig. 67 *Cirsium vulgare* (12x). Rock. 10-2-56.

Fig. 68 *Senecio aquaticus* (25x). Sp.17-34:337.

Fig. 69 *Xanthium strumarium* (4x). Sp.17-35:612.

Fig. 70 *Calystegia sepium* (10x). Ro.08-52:1073.

Fig. 71 *Brassica rapa* (20x). Sp.17-30:126.

Fig. 72 *Cochlearia officinalis* (25x). Ro.08-52:1076.

Fig. 73 *Lepidium ruderales* (25x). Rock. 2-0-12.

Fig. 74 *Erysimum cheiranthoides* (25x). Rock. 1-0-6.

Fig. 75 *Sisymbrium officinale* (25x). Rock. 1-0-6.

Fig. 76 Papillae of *Erysimum cheiranthoides* (600x). Rock. 1-0-6.

Scale bars equal 1 mm.

Carex distans

Rock.10-1-4 (n = 25): 2.13 (1.86-2.37) × 1.24 (1.09-1.50) mm

The slender, triangular seeds have a prominent cell pattern. The greatest width is at or slightly above the middle (see fig. 80). The descriptions and figures in Behre (1976c) and Körber-Grohne (1967) are directly comparable. The seeds of *C. extensa* resemble those of *C. distans*, but in *C. extensa* they are more slender, measuring ca. 1 mm in width (see also Kern/ Reichgelt 1954). Furthermore, the cell pattern of *C. extensa* is rather indistinct (Berggren 1969).

Carex disticha

Sp.17-35:600 (n = 25): 1.81 (1.63-2.07) × 1.06 (0.82-1.33) mm

As Körber-Grohne (1967) mentions, this species is extremely variable in the shape of its seed. It is flat, but sometimes so slender that the distinction with *C. elongata* becomes unclear. This led Behre (1983) to conclude that without utricles these two species cannot be separated. In our reference collection, the seeds of *C. disticha* and *C. elongata* showed a slight difference in the stipe. In *C. elongata*, no remains of the stipe adhere to the seeds, while *C. disticha* has a short stipe, which is abruptly truncated (see fig. 81). According to Behre (1976c), *C. disticha* has sharply keeled utricles, while *C. elongata* has not. The illustrations in Berggren (1969) show another clear difference. In *C. disticha* the utricles show fine, sawteeth-like projections along most of the sides, in *C. elongata* these are restricted to the upper quarter of the utricles. The characteristic appeared also clearly in our reference collection. On the basis of this criterion, the subfossil utricles proved to belong to *C. disticha* exclusively.

Carex hirta

Sp.17-30:309 (n = 1): 2.76 × 1.50 mm
 Sp.17-34:306 (n = 1): 2.82 × 1.50 mm
 Rock.10-2-52 (n = 1): 2.50 × 1.60 mm

The triangular seeds of this species are larger than most of the other triangular Carices (see fig. 82). Only *C. riparia* has similarly large seeds, these are, however, wider (cf. Knörzer 1970). The rough seed-surface of *C. hirta* also differs from *C. riparia*, which has a smooth surface.

Carex oederi s.l. (= *C. serotina/demissa*)

Rock.10-2-56 (n = 25): 1.36 (1.25-1.54) × 1.05 (0.93-1.38) mm

The small, triangular seeds have their greatest width just below the top, thus resulting in a distinctly shouldered outline (see fig. 83). The small size distinguishes them from the

similarly shaped *C. flava* and *C. lepidocarpa*. It is not possible to discriminate between *C. oederi* and *C. tumidicarpa* (cf. Van Zeist 1974; Pals 1987). Both authors give very similar size-ranges for their subfossil material attributed to this type.

Carex cf. *remota*

Sp.17-35:598 (n = 1): 2.07 × 1.29 mm

The flat, pear-shaped seed shows a distinct cell pattern on the surface. The shape reminds one of *C. cuprina/vulpina*, however, *C. remota* is more slender (see fig. 84). At a magnification of 200×, the cell pattern is clearly reticulate, in contrast to the wart-like surface of *C. cuprina/vulpina*. *C. ovalis* (= *C. leporina*) is of similar shape, but has a very indistinct cell pattern (cf. Berggren 1969).

Carex panicea

Rock.10-2-56 (n = 1): 1.95 × 1.73 mm
 Sp.17-34:332 (n = 1): 2.11 × 1.50 mm

This species has seeds that are tapered and concave towards their base (see fig. 87). The size is larger than that of *C. paniculata*, which also has a tapered, concave basal outline.

Carex paniculata

Sp.17-35:598 (n = 3): 1.56 (1.44-1.76) × 1.01 (0.90-1.13) mm
 Sp.17-34:279 (n = 2): 1.28 × 1.02 mm; 1.60 × 1.06 mm

More or less lozenge-shaped seeds widest in the middle and of a remarkably convex, basal outline (see fig. 86) are attributed to this species. The coriaceous utricle is often (partly) preserved, which allows the distinction between this species and *C. appropinquata* and *C. diandra*, with similarly shaped seeds (cf. Behre 1983). *C. paniculata* has only faint veins on the utricle, while *C. appropinquata* shows a very strong venation and *C. diandra* has one unveined side. According to Behre (1983), the seeds of *C. paniculata* are also smaller than those of *C. appropinquata*. However, Nilsson and Hjelmqvist (1967) and Jacomet *et al.* (1989) on the contrary state that *C. paniculata* has the larger seeds of the two. Since the size-ranges of both show a great overlap anyhow, it is considered that only utricles allow a reliable identification. Since only *C. paniculata* utricles were found, the bare seeds are also attributed to this species, which in addition is nowadays far more common in the Netherlands.

Carex pilulifera

Rock.10-2-56 (n = 1): 1.51 × 1.48 mm

The seeds are distinctly shouldered, the width almost equals the length (see fig. 85). The cross-section is almost circular, in contrast to the more triangular cross-section of *C. oederi*

s.l. The characteristic light ribs, as present in our reference material, could not be seen in the subfossil specimen, thus the identification remains tentative.

Carex pseudocyperus

Sp.17-34:279 (n=3): 1.70 (1.63-1.79) × 1.01 (0.90-1.18) mm
 Sp.17-34:337 (n=1): 1.75 × 0.80 mm

The very regular, triangular seed (see fig. 88) is smaller than the other triangular and unshouldered *Carex* species. The markedly nerved utricles with long beaks were also found (see fig. 89). The combination of these features is very characteristic of this species, thus making it more easily identifiable than most other *Carex* species.

Carex riparia

Sp.17-34:311 (n=1): 3.04 × 1.92 mm
 Sp.17-35:598 (n=6): 2.94 (2.72-3.17) × 1.72 (1.44-1.98) mm

The large, triangular seeds resemble those of *C. hirta* (cf. Knörzer 1970). However, *C. riparia* seeds are wider, which gives them a plump appearance (see fig. 90). Besides, the seed wall is smooth, in contrast to the rough surface of *C. hirta*. According to Kroll (1987) and Körber-Grohne (1967), *C. acutiformis* seeds resemble those of *C. riparia*. In our reference material, however, there is a great difference in size and shape, which is also apparent in Berggren's illustration (1969, plate 36, fig. 1 and 2). Some utricles were also found. They are dark with faint venation (see fig. 92).

Carex spec.

Zl.17-27:8 (n=1): 1.54 × 0.93 × 0.83 mm

This triangular seed closely resembles *Carex oederi* s.l. However, the seeds are slightly longer and have less pronounced shoulders (see fig. 91). The seed most closely resembles recent *Carex flava*. As only one specimen was found and since *Carex flava* is also rare in the Netherlands, it was decided to list this seed, although very well preserved, as *Carex* spec.

Rhynchospora alba

Rock.10-2-52 (n=1): 1.92 × 1.34 mm.

The seeds are obovate and biconvex. Twelve perianth-bristles are present. They are slightly shorter than the seed length (see fig. 93). The seed splits very characteristically, only adhering to its persisting style (cf. Grosse-Brauckmann 1974).

Schoenus nigricans

Sp.17-34:411 (n=1): 1.57 × 0.93 × 0.90 mm.

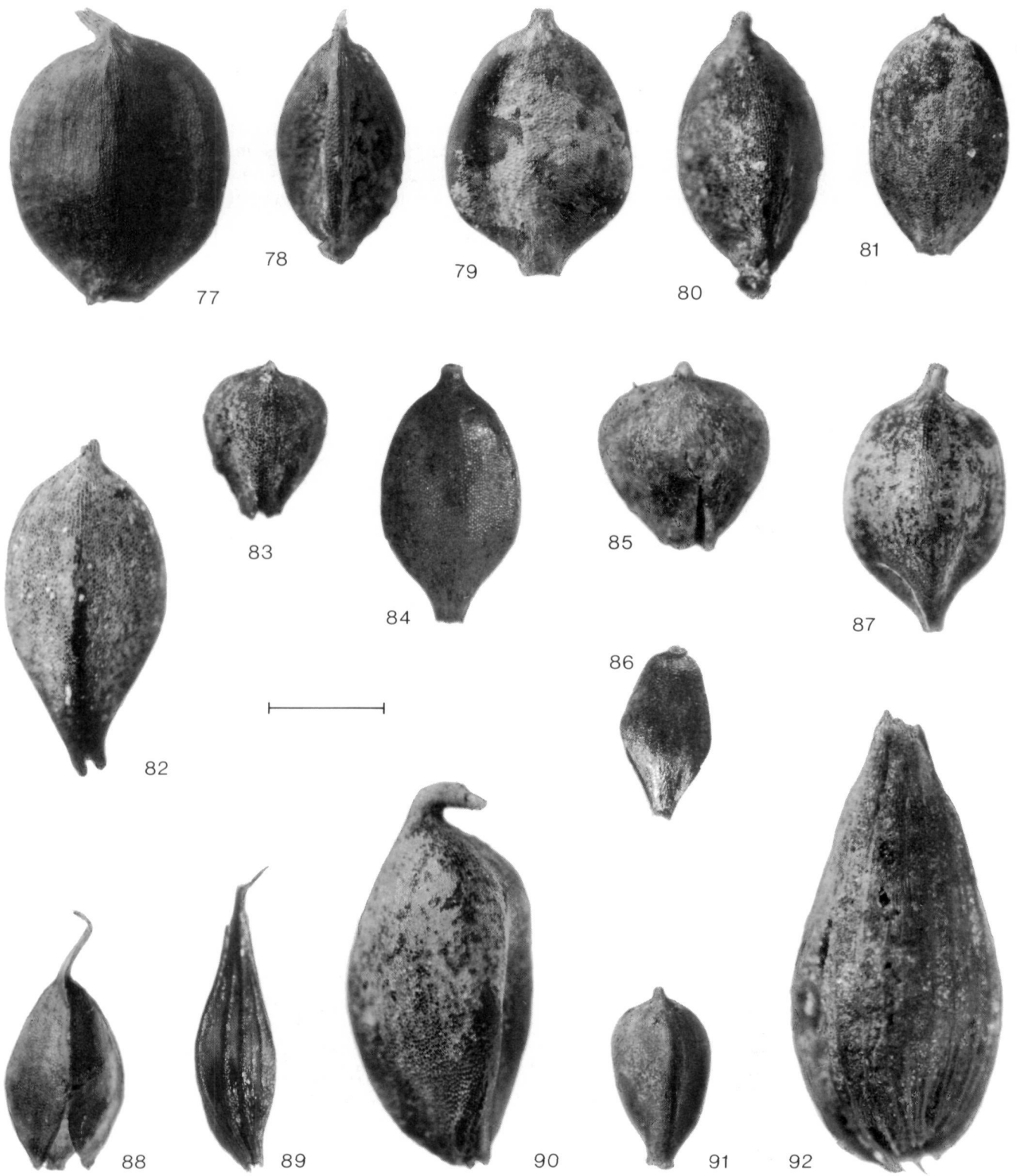
Descriptions of this species in palaeo-ethnobotanical literature are unknown to me. The triangular seed has the greatest width just above the middle. The sides are convex with smooth angles. Most striking is the lustrous whitish colour, which is due to a high silicium-content of the seed wall and which does not occur in other Cyperaceae. The size is in accordance with recent seeds (derived from the Botanical Garden, Frankfurt a.M. (n=10): 1.47 (1.30-1.67) × 0.98 (0.90-1.05) mm). The three to five perianth-bristles are not preserved in the subfossil specimen (see fig. 94).

Scirpus spec.

Körber-Grohne (1967) thoroughly discussed three common *Scirpus* species with more or less similar seeds (*S. maritimus*, *S. lacustris* (s.s.) and *S. (lacustris* ssp.) *tabernaemontani* (= *S. lacustris* ssp. *glaucus*). Recent seeds can be distinguished without much difficulty. *S. maritimus* is clearly shouldered, has seeds with a shiny surface and is the largest of the three. *S. lacustris* ssp. *tabernaemontani* is biconvex and smaller than the other two species. *S. lacustris* resembles *S. maritimus*, but is smaller and has a dull surface. According to Berggren (1969: 14), the average sizes are as follows: *S. maritimus*: 3.1 × 2.2 × 1.2 mm; *S. lacustris*: 2.7 × 1.9 × 1.0 mm; *S. lacustris* ssp. *tabernaemontani*: 2.2 × 1.6 × 0.9 mm. Material sampled from specimens of the *Rijksherbarium* was in agreement with these sizes, so it was used to identify the fossil seeds.

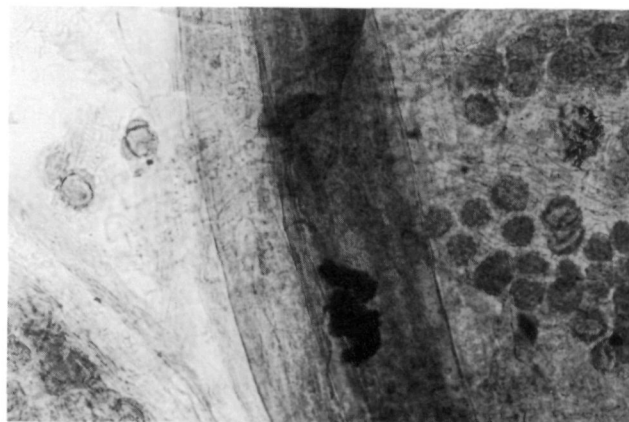
Apart from these three species, however, another species must be considered. It concerns *Scirpus triqueter*, up to now neglected in palaeo-ethnobotanical literature. At present, it is a declining species especially occurring in freshwater tidal areas (Van der Meijden 1990). It hardly occurs in brackish environments. It is clear that this species cannot be left out of consideration.

Reichgelt (1956) gives some differences between the seeds of this species and those of the very similar *S. lacustris* ssp. *tabernaemontani*. The seed size is the same, about 2-2.5 mm. The perianth-bristles show some differences. In *S. triqueter*, mostly 4 (up to 6) relatively slender bristles are present, which are usually shorter than the seed length but they can equal this length. *S. lacustris* ssp. *tabernaemontani* has mostly 6 (sometimes 4-5) bristles, which are stouter than those of *S. triqueter* and longer than the seed length. The two specimens of *S. triqueter* in our reference collection supported these criteria. In all cases where perianth-bristles were present in the subfossil specimens, these were of the stout type. Besides, if well preserved, they were longer than the seed. Many, however, were broken. Furthermore, often six bristles (or remains) were noticed. The stoutness, however, is considered conclusive. Since no slender and short perianths were seen, all specimens without perianths were also attributed to *S. lacustris* ssp. *tabernaemontani*.

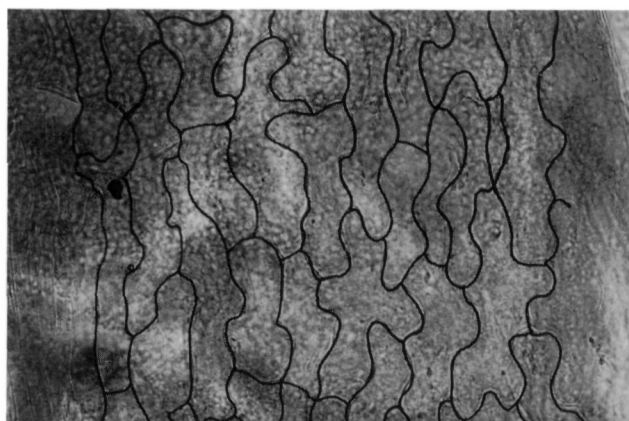




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- Fig. 77 *Carex acuta*-type (20x). Sp.17-35:598.
 Fig. 78 *Carex acutiformis* (20x). Sp.17-35:598.
 Fig. 79 *Carex cuprina*-type (20x). Sp.17-30:126.
 Fig. 80 *Carex distans* (20x). Rock. 10-2-56.
 Fig. 81 *Carex disticha* (20x). Sp.17-34:311.
 Fig. 82 *Carex hirta* (20x). Sp.17-34:306.
 Fig. 83 *Carex oederi* s.l. (20x). Rock. 10-2-56.
 Fig. 84 *Carex cf. remota* (20x). Sp.17-35:598.
 Fig. 85 *Carex pilulifera* (20x). Rock. 10-2-56.
 Fig. 86 *Carex paniculata*-type (20x). Sp.17-35:598.
 Fig. 87 *Carex panicea* (20x). Sp.17-34:332.
 Fig. 88 *Carex pseudocyperus* (20x). Sp.17-35:436.
 Fig. 89 *Carex pseudocyperus* utricule (12x). Sp.17-35:598.
 Fig. 90 *Carex riparia* (20x). Sp.17-35:598.
 Fig. 91 *Carex spec. (cf. flava)* (20x). ZI.17-27:8.
 Fig. 92 *Carex riparia* utricule (20x). Sp.17-35:598.
 Fig. 93 *Rhynchospora alba* (20x). Rock. 10-2-52.
 Fig. 94 *Schoenus nigricans* (20x). Sp.17-34:411.
 Fig. 95 *Scirpus sylvaticus* (20x). Rock. 10-2-56.
 Fig. 96 *Scirpus lacustris tabernaemontani* (20x). Sp.17-30:126.
 Fig. 97 *Scirpus maritimus* (20x). Nh.09-89:3036.
 Fig. 98 *Artemisia cf. vulgaris* with pollen grains (c. 250x). Rock. 2-0-12.
 Fig. 99 Cell pattern of *Artemisia cf. vulgaris* (250x). Rock. 2-0-12.

Scale bars equal 1 mm, except for fig. 89.

Scirpus lacustris ssp *tabernaemontani* (= ssp *glaucus*).

Sp.17-34:278 (n=25): 2.23 (1.92-2.59) × 1.62 (1.41-1.79) mm

Sp.17-35:600 (n=25): 2.18 (1.89-2.40) × 1.45 (1.18-1.73) mm

Nh.09-89:3036 (n=18): 2.25 (1.95-2.62) × 1.50 (1.34-1.76) mm

Rock.10-2-52 (n=25): 2.15 (1.92-2.53) × 1.51 (1.31-1.76) mm

The sizes clearly fall in the range of this species. The majority of the subfossil material still had the perianth-bristles (see fig. 96), which are absent in *S. maritimus*. The seeds are always biconvex; triangular forms, resembling *S. lacustris* s.s. were not found.

Scirpus maritimus

Nh.09-89:3036 (n=50): 3.13 (2.78-3.58) × 2.29 (1.76-2.85) mm

Rock.1-0-6 (n=25): 2.92 (2.56-3.68) × 1.94 (1.66-2.14) mm

Sp.17-35:615 (n=2): 3.26 × 2.11 mm; 3.81 × 2.24 mm

The plump seeds of this species often still had the shiny outer layer. After corrosion a layer with a coarse cell pattern remains. The prominent shoulders further characterize this species (see fig. 97). Perianth-bristles (deciduous according to Berggren 1969) were never found.

Scirpus sylvaticus

Sp.17-34: div. (n=8): 0.86 (0.78-0.93) × 0.55 (0.48-0.67) × 0.40 (0.38-0.45) mm

This small Cyperaceae seed closely resembles *Cyperus fuscus*. In recent seeds, *Scirpus sylvaticus* has perianth-bristles, which are lacking in *Cyperus fuscus*. However, their absence can not be used with confidence for subfossil material, since these bristles are more or less deciduous. One of the subfossil seeds did still have one perianth-bristle (see fig. 95). In palaeobotanical descriptions, authors who have found one of these species seldom discuss the difference with the other species. Only Wieserowa (1979) and Knörzer (1981) mention that *Cyperus fuscus* has three equally wide sides in contrast to the *Scirpus* species. Wieserowa (1979: 158) reported both species. In her material, the lengths are equal but the width of *Cyperus fuscus* is 0.45-0.50 mm and of *Scirpus sylvaticus* 0.6-0.7 mm. The perianth-bristles were not preserved in Wieserowa's *Scirpus*. Wasylkowa (1978: 142) found *Scirpus sylvaticus* seeds, some of which still possessed perianth-bristles. Size: 0.95 (0.7-1.15) × 0.63 (0.45-0.7) mm. Because of the greater similarity of the present seeds to the Polish *S. sylvaticus* size-ranges and the presence of the perianth-bristle on one specimen, all seeds are attributed to *Scirpus sylvaticus*.

Ericaceae

Andromeda polifolia

Nh.09-89:3009(n=1): 1.09 × 0.96 mm

Nh.09-89:3048(n=1): 1.05 × 0.90 mm

Zl.17-22:1 (n=3): 0.99 (0.80-1.12) × 0.73 (0.64-0.83) mm

Recent seeds collected from wild plants (Joensuu, Finland, via Hortus of Joensuu) produced the following measurements (n=10): 1.19 (0.99-1.23) × 0.78 (0.66-0.90) mm.

The seeds have an irregularly egg-shaped outline with a sunken, oval hilum near the top. The cross-section is elliptic. The brown surface is lustrous (see fig. 100). Kroll (1987) found leaves of cf. *Andromeda polifolia* among many other heath species, Grosse-Brauckmann (1974, 1976) gives illustrations of stems and leaves from natural deposits. Seeds have so far not been described in palaeo-ethnobotanical literature.

Vaccinium spec.

Zl.17-27:9 (n=1): 1.17 × 0.78 mm.

Tallantire (1976) discusses the identification of subfossil *Vaccinium* seeds. His conclusion is that, if a reasonably large number of well preserved seeds is present, specific identification seems possible. Since only one seed was found in the present study, there was no sound base for further identification.

Euphorbiaceae

Euphorbia palustris

Sp.17-30:127 (n=2): 3.42 × 2.88 mm; 3.74 × 2.98 mm.

Only Körber-Grohne (1967) has described the seeds of this species. The seeds are egg-shaped, the smaller end being truncated on one side. This is the place where the caruncula is situated in recent seeds (Brouwer/ Stählin 1973). On the longitudinal axis, the hilum is present as a small groove (see fig. 102).

Gentianaceae

Centaurium spec.

Rock.10-1-4 (n=15): 0.41 (0.35-0.45) × 0.33 (0.27-0.38) mm

The small seeds have a distinctly reticulate surface pattern. They resemble the equally small seeds of *Calluna vulgaris* and *Erica tetralix*. The very fragile seed of *Calluna* has a relatively large, collar-like hilum and finer epidermis-cells than *Centaurium*. In *Calluna*, the cell-walls are more or less straight. Seeds of *Erica* and *Centaurium* are less fragile and have cell-walls like jig-saw puzzle pieces (more prominent in *Erica*). *Erica* has smaller epidermis cells than *Centaurium*. In *Erica*, about nine cells are present along the length of the seed, in contrast to ca. five cells in *Centaurium*.

Gramineae

For the identification of waterlogged Gramineae fruits the publication of Körber-Grohne (1964) is indispensable. Carbonized specimens are often even more difficult to identify than uncarbonized ones, but species with a very characteristic hilum (e.g. *Agrostis*) can be identified beyond the level of Gramineae indet.

Danthonia (Sieglingia) decumbens

Rock.10-2-56 (n = 14): 2.38 (2.14-2.56) × 1.32 (1.15-1.50) mm

The broadly oval fruits of *Danthonia* show a very characteristic bright whitish hilum covering 26-37% of the fruit length. This species is not included in Körber-Grohne's (1964) publication, where it keys out to *Phalaris arundinacea* or *Molinia caerulea*. The bright hilum of *Danthonia*, which is a little shorter than that of *Molinia* and not lateral as in *Phalaris*, makes a clear distinction between these species possible.

Glyceria fluitans

Sp.17-34:580 (n = 50): 2.40 (2.16-2.70) × 0.98 (0.78-1.17) mm

The measurements concern carbonized fruits. The *Glyceria* species are characterized by a long hilum, which ends near the apex. In some cases, carbonized subfossil specimens still had the typical bifurcated projection on top of the seeds (see fig. 37). The surface cells are isodiametrical. The different species can be distinguished by their size (Dickson 1970: 240; Hubbard 1976; Jansen 1951). *G. maxima* has the smallest seeds (sic!), *G. declinata* and *G. plicata* (united in *G. notata* at present) have intermediate sizes (up to 2.5 mm), *G. fluitans* is the largest. The remarkable concentration of *G. fluitans* in Spijkenisse 17-34 is discussed in 4.5.5.

Phalaris arundinacea

Sp.17-35:612 (n = 8): 1.81 (1.47-2.05) × 1.14 (0.99-1.28) mm

The lateral position of the hilum, which covers about half the fruit length, makes this species unmistakable.

Molinia caerulea

Apart from seeds which possess a very stout hilum reaching up to 2/3 of the fruit length, some grass stems also were found. These did not have the adventive bud which characterizes *Phragmites*-stems. Consequently, they resembled cereal straw. Examination of the epidermis revealed that the characteristic cereal epidermis, with alternating longitudinal rows with and without stomata (cf. Brinkkemper 1991), was absent. Instead rows of one long and usually two short cells

(see fig. 103) were present, very similar to Grosse-Brauckmann's (1972) illustration of the *Molinia*-epidermis. Since other Gramineae species might also have this epidermis-type, the stems are recorded as *Molinia*-type stems in the present study.

Parapholis strigosa

Ro.08-52:1073 (n = 1): 3.1 × 1.1 mm

Only Van Zeist (1974) described the fruits of this species. The central hilum measures 600 × 90 µm in the present specimen. In combination with the size of the fruit, all other Gramineae can be excluded. The epidermis cells are hardly discernable in this species (see fig. 105).

Puccinellia distans

Ro. 10-2-58 (n = 25): 1.44 (1.19-1.60) × 0.72 (0.65-0.82) mm

Puccinellia species have remarkably regular epidermis patterns of rectangular cells. The ovate hilum is blackish. The species differs from *P. maritima* by its smaller size (cf. Van Zeist 1974; Behre 1976c).

Hypericaceae

Hypericum quadrangulum

Sp.17-30:309 (n = 20): 0.72 (0.64-0.82) × 0.32 (0.28-0.36) mm

Sp.17-35:600 (n = 7): 0.70 (0.57-0.79) × 0.31 (0.28-0.35) mm

The cylindrical seeds have a distinctly reticulate surface. They are smaller than most of the other *Hypericum* species. *H. elodes* is even smaller than *H. quadrangulum* (0.5-0.6 mm in our reference material). *H. montanum* is similar in size to *H. quadrangulum*, but in *H. montanum*, the surface pattern consists of a very fine reticulum which is hardly visible.

Juncaceae

As for uncarbonized grass fruits, the key published by Körber-Grohne (1964) is of great value for the identification of *Juncus* seeds. It provided the base for the following identifications.

Juncus effusus-type

The subfossil seeds of *J. effusus*, *J. inflexus* and *J. subuliflorus* (= *conglomeratus*) are very similar. They are included in this type after Behre (1976c, 1983), Kroll (1987) and Pals (1987).

Juncus maritimus

Rock.10-2-58 (n = 25): 0.70 (0.61-0.77) × 0.33 (0.25-0.39) mm

The sizes have been measured on flattened seeds in microscopic slides (as in Körber-Grohne 1964). The characteristic thickening of some but not all of the transverse cell walls is very striking. These thick-walled transverse cells alternate with cells with thinner walls. (see *fig. 104; 106*; Körber-Grohne 1964: Taf. III, Abb. 2). Subfossil records of this species are unknown to me. The size range is very similar to the range in recent seeds reported by Körber-Grohne.

Luzula multiflora

Nh.09-89:3009 (n = 1): 1.06 × 0.77 mm

Nh.09-89:3043 (n = 1): 1.10 × 0.75 mm

The oval seeds are lustrous and show a fine point at one end. The surface has an isodiametric reticulum. According to Körber-Grohne and Piening (1983: 59), *L. campestris* has an elongated reticulum. Moreover, seeds of *L. campestris* are almost as wide as long (Reichgelt 1964; Van der Meijden 1990). Recent specimens of *L. multiflora* in our reference collection (n = 10, Valais, Switzerland: Hortus Geneva) measured 1.24 (1.18-1.27) × 0.81 (0.74-0.87) mm, seeds of *L. campestris* (n = 10, Texel, Netherlands: IPL) measured 1.16 (1.09-1.24) × 0.93 (0.90-0.99) mm, which indicates that the width is a reliable criterion for separating the two species.

Juncaginaceae

Triglochin palustris

Zl.17-27:9 (n = 15): 6.07 (4.11-7.82) × 0.86 (0.63-1.03) mm

The very slender, awl-shaped fruits are characteristic. The basal horseshoe-shaped hilum and the often bifurcated apex further typify this species (see *fig. 107*).

Labiatae

Galeopsis bifida-type

Sp.17-35:612 (n = 8): 3.47 (3.23-3.71) × 2.78 (2.50-3.10) mm

The oval seeds have a characteristic, large hilum at the pointed end. The large width of the seeds excludes those of *G. ladanum/segetum*. *G. bifida*, *G. speciosa* and *G. tetrahit* are, however, very similar (see also Fredskild 1978; Wasylkova 1978; Jacomet *et al.* 1989) and they are lumped together in the *G. bifida*-type. *G. bifida* is ignored by many other authors, remarking upon the similarity between *G. tetrahit* and *G. speciosa* (e.g. Allison *et al.* 1952; Behre 1970, 1976c, 1983; Jacquet 1988; Van Zeist 1974; Van Zeist/Palfenier-Vegter 1983). Knörzer (1976) mentions the similarity between *G. tetrahit* and *G. bifida* and leaves *G. speciosa* out of consideration. According to Van der Meijden (1990), *G. bifida* occurs in ruderal places in peaty areas, especially near reed (*Phragmites*) piles and along ditches. This makes an occurrence of this species in prehistoric times quite possible.

Linaceae

Linum catharticum

Rock.10-2-56 (n = 6): 1.31 (1.25-1.44) × 0.80 (0.74-0.86) mm

The shape and the pronounced beak are similar to those of *Linum usitatissimum*. Cultivated linseed, however, has much larger seeds.

Malvaceae

Althaea officinalis

09-89:3009 (n = 6): 3.30 (2.91-3.62) × 3.01 (2.46-3.42) mm

The disc-shaped seeds are of uneven thickness, the outer edge being the thickest. In consequence, the cross section is wedge-shaped. The surface has coarse ribs which fade out towards the thinner part.

Myricaceae

Myrica gale

09-89:3009(n = 25): 2.46 (1.95-3.20) × 2.25 (1.89-2.72) mm

The characteristic fruits consist of a central nut enveloped by closely adhering bracts, both bracts are pointed at one end. The central nut is fused with two sterile bracts. The nut is often split in the middle. The small whitish glands on the surface are well preserved in some fruits. Apart from the fruits, some leaf fragments and buds of *Myrica gale* were also found. The leaves are obovate, the abaxial side shows whitish glands. The bud scales have pale translucent margins and hairs along the lower part of the margin, similar to those described by Tomlinson (1985).

Najadaceae

Najas marina

Sp.17-34:337 (n = 13): 3.61 (3.01-4.54) × 1.23 (0.83-1.92) mm

Najas seeds are oblong-ellipsoid and show a distinct reticulation (see *fig. 108*). They have a characteristic reddish-brown colour in the present samples. The seeds easily split into two halves, in which state they were usually recovered.

Onagraceae

Epilobium hirsutum-type

Sp.17-35:612 (n = 25): 1.01 (0.90-1.17) × 0.54 (0.47-0.66) mm

The seeds are narrowly obovate and have fine warts. The ventral hilum widens towards the apex. Seeds of *E. hirsutum*, *E. montanum*, *E. parviflorum*, *E. obscurum*, *E. roseum* and *E. tetragonum* are very similar. Jacomet (1986: 174) gives provisional distinguishing characteristics which, according to her, need further examination. *E. montanum* accord-

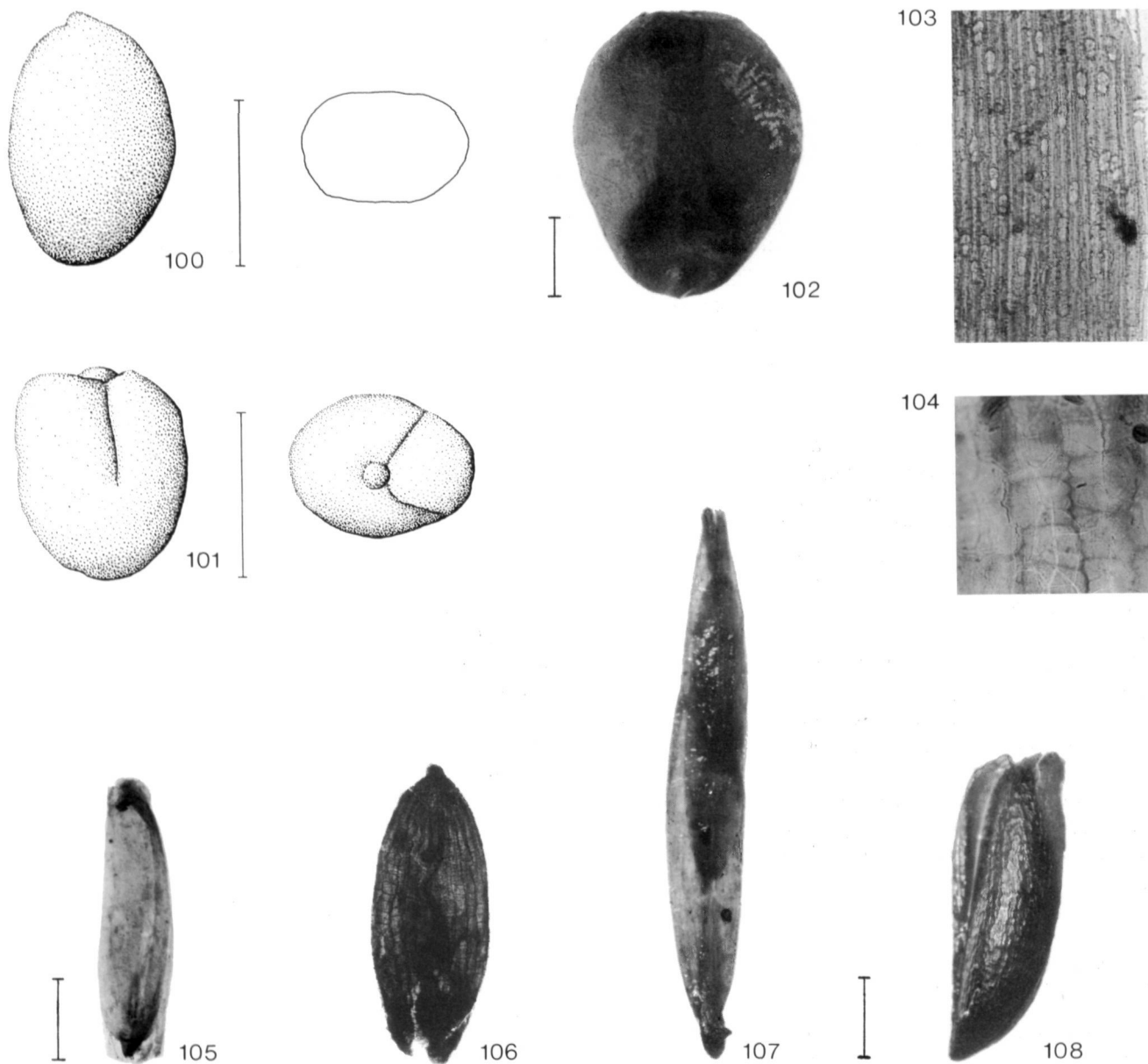


Fig. 100 *Andromeda polifolia* (25x). Nh.09-89:3009.

Fig. 101 *Trifolium repens/fragiferum* (25x). Sp.17-30:127.

Fig. 102 *Euphorbia palustris* (12x). Sp.17-30:127.

Fig. 103 Epidermis cells of *Molinia*-type stem (240x).

Fig. 104 *Juncus maritimus* (240x). Rock. 10-2-58.

Fig. 105 *Parapholis strigosa* (12x). Ro.08-52:1073.

Fig. 106 *Juncus maritimus* (60x). Rock. 10-2-58.

Fig. 107 *Triglochin palustris* (12x). Zl.17-27:9.

Fig. 108 *Najas marina* (12x). Sp.17-34:337.

Scale bar equals 1mm.

Table 40. Sizes of *Epilobium* species.

<i>E. hirsutum</i>	
Leiden, Netherlands: IPL, Leiden	0.97 (0.93-1.05) × 0.48 (0.45-0.51) mm
Stockholm, Sweden: Hortus Bergianus	0.98 (0.93-1.05) × 0.51 (0.45-0.54) mm
<i>E. montanum</i>	
Roermond, Netherlands: IPL, Leiden	1.10 (0.96-1.20) × 0.41 (0.39-0.42) mm
Leiden, Netherlands: Hortus Leiden	0.95 (0.84-1.05) × 0.41 (0.34-0.45) mm
<i>E. obscurum</i>	
Duisburg, Germany: Bot. Garden Duisburg	1.03 (0.93-1.14) × 0.50 (0.45-0.54) mm
Buncloody, Ireland: Hortus Glasnevin	0.91 (0.87-0.96) × 0.44 (0.42-0.45) mm
<i>E. parviflorum</i>	
Molenaarsgraaf, Netherlands: IPL, Leiden	0.97 (0.90-1.05) × 0.48 (0.45-0.51) mm
Berlin, Germany: Bot. Garden Berlin	0.95 (0.90-1.05) × 0.46 (0.42-0.50) mm
<i>E. tetragonum</i>	
Hausen, Germany: IPL, Leiden	0.96 (0.93-1.02) × 0.43 (0.42-0.45) mm
Helsingborg, Sweden: Bot. Garden Helsingborg	0.93 (0.87-0.96) × 0.43 (0.40-0.46) mm

ing to her is larger than 1 mm (average 1.18 mm), *E. hirsutum* measures around 1 mm and *E. parviflorum*, *E. roseum* and *E. tetragonum* should be a little smaller than 1 mm. *E. hirsutum* has relatively large papillae, while the other species have very small, often even hardly visible warts. According to Knörzer (1981: 69), *E. hirsutum* has slightly broader seeds than the other species. The further examination recommended by Jacomet has been carried out on our reference material. For every sample ten seeds were measured (see table 40).

It seems that size cannot be used as the only criterion for the identification of *Epilobium* seeds but the warts may provide additional information. The value of this characteristic for subfossil material, however, is difficult to assess. The uncorroded specimens in the present study showed very clear warts. The seeds have therefore been listed as *Epilobium hirsutum*-type.

Papilionaceae

Trifolium repens/fragiferum

Sp.17-30:127 (n=6): 1.29 (1.15-1.44) × 1.09 (0.80-1.22) mm

The radicle of these seeds (see fig. 101) is larger than in most *Trifolium* species. In our reference material, such large radicles occur in both *T. repens* and *T. fragiferum*. According to Behre (1976c: 103), *T. fragiferum* is more symmetrical than any other *Trifolium* species. However, in *T. repens* this symmetry also occurs (cf. Knörzer 1970) and in consequence, no distinction has been made here.

Vicia spec.

Some waterlogged seeds of *Vicia* occurred in several samples. They were flattened, but the large hilum could still clearly be discerned on the otherwise smooth, leather-like seeds. Several authors have expressed the importance of the length of the hilum in relation to the total circumference of

the seeds for further identification of *Vicia* seeds. Jacomet *et al.* (1989) stated that the length-width ratio of the hilum is a valuable characteristic, but they did not provide further data.

In order to obtain quantitative information, the (dried) seeds present in our reference collection were measured. Both the ratio circumference (= $\pi \cdot D$)/length of the hilum (A) and length/width of the hilum (B) were calculated. These dimensions were measured as indicated in figure 109. It should be noted that the length of the hilum thus obtained is slightly shorter than the actual length, but if consistently applied, this is of minor importance. Only in *Vicia sepium*, where the hilum covers more than half of the circumference, the measurements were taken in three or four steps. The width of the hilum was measured in the middle of the longitudinal axis. Ten seeds were measured from each sample of our collection. The data obtained have been given in table 41. The size ranges and A-values are in agreement with those published by Kulpa (1974: 159-164).

On the basis of these data (waterlogged) seeds can be distinguished according to the following key. Preliminary investigations concerning carbonized material revealed that the seed coat can easily disappear. In that case, the impression of the hilum between the cotyledons is visible. This impression is much wider and slightly longer than the original hilum. Furthermore, the increase in width differs between the various species. Only specimens on which the original hilum on the seed coat is still present, can be identified with the following identification key:

1a. Seeds at least 6 mm in diameter, carbonized specimens rarely smaller, length/width ratio of hilum < 5

..... *Vicia faba*

1 b. Seeds smaller and/or length/width ratio of the hilum > 5.

...2

Table 41. Sizes of *Vicia* species.

	diameter (mm)	A	B
<i>V. cracca</i>			
Leiden, Netherlands: IPL	3.00 (2.73-3.29)	3.4-3.7	5.4-6.6
Eck en Wiel, Netherlands: IPL	2.63 (2.51-2.76)	4.2-4.7	4.6-5.8
<i>V. faba</i> var. <i>minor</i>			
Irnsing, Germany: IPL	10.6 (9.67-11.5)	6.5-8.1	3.6-4.8
<i>V. hirsuta</i>			
Besançon, France: Botanical Garden	2.43 (2.20-2.70)	3.8-4.4	6.8-8.9
Schin op Geul, Netherlands: IPL	2.63 (2.39-2.85)	3.5-4.0	7.0-9.6
<i>V. lathyroides</i>			
Gatersleben, Germany: Gene-centre	1.74 (1.46-1.89)	7.8-14.7	1.8-2.4
<i>V. sativa</i> ssp. <i>angustifolia</i>			
Roermond, Netherlands: IPL	2.64 (2.42-2.85)	5.0-6.6	3.3-4.4
Schin op Geul, Netherlands: IPL	3.00 (2.48-3.56)	4.4-6.5	3.8-5.7
<i>V. sativa</i> ssp. <i>sativa</i>			
Leiden, Netherlands: Botanical Garden	4.33 (3.72-4.71)	5.8-7.3	5.1-7.1
<i>V. sepium</i>			
Bemelerberg, Netherlands: IPL	3.43 (2.79-3.66)	1.7-2.1	16.4-22.9
Zwolle, Netherlands: IPL	3.35 (3.13-3.62)	1.6-1.7	19.5-25.2
<i>V. tetrasperma</i>			
Helsingborg, Sweden: Botanical Garden	1.95 (1.86-2.02)	4.8-5.4	2.8-3.4
Espoo, Finland: Hortus Helsinki	2.00 (1.89-2.17)	4.8-6.1	2.9-3.5

2 a .Hilum very short and relatively wide. Circumference/hilum length ratio > 7.5, length/width ratio of hilum < 2.5. Recent seeds with distinct warts, which are also apparent in artificially carbonized specimens. Largest diameter < 1.9 mm.

..... *Vicia lathyroides*

2 b .Circumference/hilum length ratio < 7.5, length/width ratio of hilum > 2.5. No distinct warts, largest diameter seldom smaller than 1.9 mm

...3

3 a .Hilum covers ca. 1/2 — 2/3 of the circumference of the seed and hilum more than ten times longer than its width

..... *Vicia sepium*

3 b .Hilum covering at most 1/3 of the circumference of the seed, less than ten times longer than its width

...4

4 a .Length/width ratio of hilum < 4, uncarbonized seeds smaller than 2.3 mm

..... *Vicia tetrasperma*

4 b .Length/width ratio of hilum > 4 and/or seeds larger

...5

5 a .Seeds larger than 3.7 mm, hilum covering about 1/6 - 1/7 of the circumference

..... *Vicia sativa sativa*

5 b .Seeds smaller, hilum covers 1/3 - 1/7 of the circumference

...6

6 a .Length/width ratio of the hilum > 6.7, seeds relatively small, up to 2.85 mm.

..... *Vicia hirsuta*

6 b .Length/width of the hilum < 6.7.

...7

7 a .Length/width of the hilum < 4.5 and/or circumference/hilum length ratio > 5.2.

..... *Vicia sativa angustifolia*

7 b .Length/width of the hilum > 5.7 and/or circumference/hilum length ratio < 4.1.

..... *Vicia cracca*

7 c .Length/width ratio of the hilum 4.5-5.7 and circumference/hilum length ratio 4.1-5.2.

Vicia cracca/Vicia sativa angustifolia

Vicia cf. *hirsuta*

Ro.08-52:1069 (n=3): D = 2.10 (1.8-2.5) mm

The hilum could not be measured, the largest diameter is in the lower range of *Vicia hirsuta*. The identification therefore is tentative.

Vicia cracca

Gv.17-55: 2 (n=1): D = 2.88 mm, A = 4.95, B = 5.9.

Ro.08-52:1069 (n=2): D = 2.42-2.64 mm, A = 3.81-4.40, B = ?

The diameter and the ratios indicate that *Vicia cracca* is

concerned here. In the flattened specimen from Geervliet, the diameter is probably too large, resulting in a value for A which is too high.

Plantaginaceae

Plantago coronopus

Rock.1-0-6: (n=2): 0.98×0.65 mm; 1.07×0.64 mm

The small, oval seeds have a distinct, light hilum near the middle. *Plantago major* can be equally small, but can readily be distinguished by the two hila and the ridged surface. The other *Plantago* seeds are distinctly larger. The size closely corresponds to Behre's (1976c) description and to our reference material (Noordwijk, Netherlands: IPL, Leiden), which measures $1.02 (0.93-1.11) \times 0.60 (0.54-0.66)$ mm (n=10). Other subfossil records of this species are unknown to me.

Plantago maritima

Rock.10-2-52 (n=3): $2.60 (2.30-2.88) \times 1.03 (0.93-1.12)$ mm

The elliptical brownish seeds have a conspicuous circular hilum just out of the middle. The unmistakable, conical capsule lids were also found.

Plumbaginaceae

Limonium vulgare

Ro.08-52:1069 (n=1): 4.47×1.32 mm.

Ro.08-52:1069 (n=5): length calyces: $5.34 (4.72-5.80)$ mm.

In Rockanje 08-52, several calyces of this species were found (see fig. 111). The calyces have five ribs, in contrast to those of *Armeria maritima* which have ten ribs. Furthermore, *Limonium* calyces only bear hairs on some ribs while *Armeria* ribs are more densely covered with hairs (cf. Van Zeist 1974; Behre 1976c). Some calyces still bore a seed, the apex of which is pentagonal in cross section. The surface is regularly bumpy (see fig. 113).

Polygonaceae

Polygonum hydropiper

Sp.17-34:327 (n=8): $3.24 (2.85-3.62) \times 2.16 (1.86-2.46)$ mm

Sp.17-35:598 (n=7): $3.56 (3.33-3.84) \times 2.22 (1.98-2.43)$ mm

The ovate fruits with tapering apex show a fine reticulum, best visible in light from a lateral source. Only *Polygonum mite* can also be slightly striate. Jacomet (1986) demonstrated that the size is a useful criterion in distinguishing these species. *Polygonum mite* is seldom larger than 3 mm and seldom wider than 2 mm, whereas *P. hydropiper* is usually larger than 3 mm and wider than 2 mm. *P. hydropiper* also has a more clearly visible reticulum. Thus, the present material is attributed to *P. hydropiper*.

Polygonum lapathifolium

Sp.17-35:612 (n=25): $2.41 (2.11-2.75) \times 2.00 (1.82-2.40)$ mm

This species can be subdivided into four subspecies with different ecology (cf. Van der Meijden 1990). This division is mainly based on fruits, which is most promising for palaeobotanical research. However, the size range of the present fruits does not allow a definite identification. Only ssp. *lapathifolium*, with fruits smaller than 2 mm (according to Van der Meijden), but 1.7-2.8 mm according to Berggren (1981), might be excluded. Pals' (1987) conclusion that the size of fruits is apparently not a reliable criterion for the identification of subspecies of *P. lapathifolium* seems to be the safest.

Rumex conglomeratus

Sp.17-35:598 (n=6): $2.38 (2.24-2.75) \times 1.98 (1.57-2.46)$ mm

Some specimens of *Rumex* with more or less complete perigons could be attributed to this species. The measurements do include these perigons. There is no difference in the size of the tubercles present on the long tongue-shaped perigons (see also Kubát 1979; Knörzer 1970). Without these characteristic perigons identification is not possible. In consequence, bare fruits are listed as *Rumex* spec.

Rumex hydrolapathum

Sp.17-34:375 (n=10): $3.28 (3.07-3.65) \times 2.16 (1.86-2.50)$ mm

A large part of the fruits still had perigons. These are elongated and hardly indented. In contrast to *R. crispus* and *R. obtusifolius*, the perigon base of *R. hydrolapathum* is V-shaped, whereas that of the former two species has an inverse V-shape (cf. Van der Meijden 1990). The fruit of *R. hydrolapathum* is larger than that of the other *Rumex* species (cf. Knörzer 1970; Jacomet *et al.* 1989). The measurements concern fruits without perigons.

Potamogetonaceae

Zannichellia palustris ssp. *pedicellata*

Sp.17-34:278 (n=10): $2.45 (2.21-2.62) \times 0.71 (0.61-0.80)$ mm

with projections: $3.90 (3.62-4.80)$ mm

If complete, the remarkable fruits of this species have long projections at both ends and a row of smaller bristles on the dorsal side. The long projections are characteristic of this subspecies (cf. Behre 1976c, 1983; Van Zeist 1974). Large numbers of these fruits as found in Spijkenisse 17-34 are exceptional in palaeobotanical research.

Primulaceae

Centunculus minimus/*Samolus valerandi*

Sp.17-34:327 (n=1): 0.59 × 0.33 mm

Ro.08-52:D-I (n=25): 0.58 (0.50-0.68) × 0.40 (0.34-0.46) mm

Only Behre (1983) discusses the difference between these small Primulaceae species, which closely resemble each other. Behre identified his single specimen as *Samolus valerandi* on account of the absence of the warts, which characterize *Centunculus minimus*. The recent seeds of *Centunculus* in our reference collection did indeed show these warts. However, only slight finger pressure is sufficient to remove these warts. In the subfossil material, these warts were sometimes still present. They can best be recognized with a transmitted light microscope at a magnification of 200×. The warts are intertwined on the seedcoat. In my opinion, the absence of this characteristic trait does not allow identification of single specimens as *Samolus valerandi*, in view of the easy removal of the warts in *Centunculus*. Only the peaty base of the Dunkirk I deposit covering the site Rockanje 08-52 yielded a large number of seeds, all without any trace of warts. These seeds were attributed to *Samolus valerandi*.

Lysimachia thyrsiflora

Sp.17-34:337 (n=1): 1.45 × 0.78 × 0.59 mm

Lysimachia seeds resemble those of *Anagallis arvensis*. *Anagallis* can be recognized by the small wart-like scales, while in *Lysimachia* the surface bears air-containing tissue. In *L. thyrsiflora* the basal part is regular oval in shape and slightly curving (boat-shaped) (see fig. 110; Katz *et al.* 1965, pl. 74, fig. 8). The thickened margin which is characteristic of *L. vulgaris* (cf. Knörzer 1970; Katz *et al.*, pl. 74, fig. 2) is absent in *L. thyrsiflora*. Apart from some records published by Katz *et al.* (1965), descriptions of palaeobotanical material of *Lysimachia thyrsiflora* are unknown to me. Seeds of *L. nummularia*, a common species in the Netherlands, are not present in our reference collection. Knörzer (1970: 98) did not have these seeds at his disposal either. Therefore, roughly one hundred specimens of the *Rijksherbarium* were inspected for seeds, however, also with a negative result. Apparently, this species nowadays mainly reproduces vegetatively. A comparable situation can be seen in reed (*Phragmites australis*) which also only seldom develops seeds. The consequence of the inability to find *L. nummularia* seeds is that it remains unknown to me whether these seeds can be distinguished from the other two species.

Lysimachia vulgaris

Nh.09-89:3009 (n=14): 1.39 (1.09-1.63) × 0.92 (0.67-1.34) mm

The thickened margin around the basal (abaxial) part of the seed and the irregularly polygonal base typify this species (see fig. 112). The basal part is also more flattened than in *L. thyrsiflora*.

Ranunculaceae

Caltha palustris

Sp.17-34:337 (n=10): 2.53 (1.85-2.82) × 1.14 (0.90-1.34) mm

The comma-shaped fruits are usually constricted around the middle. The basal part is smooth-walled, the smaller upper part is rather spongy.

Ranunculus repens-type

Sp.17-35:598 (n=15): 2.57 (2.24-2.94) × 2.02 (1.76-2.43) mm

In most samples distinct *R. repens* fruits were present. In several cases, however, fruits were present that resembled *R. lingua* because of their slenderness. Especially in larger samples of *R. repens*, more deviating specimens occurred. It seems likely that these also belong to *R. repens*. To account for the possible occurrence of *R. lingua*, the fruits are all listed as *R. repens*-type.

Rosaceae

Crataegus laevigata

Sp.17-34:327 (n=1): 6.21 × 3.65 × 2.24 mm

The flattened ventral side indicates that this fruit stone belongs to *Crataegus laevigata* and not to *C. monogyna*, which is round in cross-section. Other Rosaceae fruit stones do not show the characteristic combination of size and shape (see fig. 114).

Prunus spinosa

Sp.17-34:436 (n=1): 12.31 × 9.04 × 6.29 mm

Sp.17-34:279 (n=2): 11.14 × 7.07 × 5.11; 7.99 × 6.02 × 5.24 mm

Sp.17-35:612 (n=2): 7.73 × 6.03 × 4.85; 8.78 × 6.94 × 5.76 mm

The highly variable fruit stones are characterized by their large size, the very rough surface and a conspicuous ridge (cf. fig. 94 in Renfrew 1973). Knörzer and Müller (1968) discuss the differences with other *Prunus* species. The distinction from small *Prunus insititia* var. *juliana* fruitstones can sometimes be difficult to make, but this taxon is highly improbable in the Iron Age material from Voorne-Putten. The form-groups ("Formenkreise") which Baas (1974, 1979) recognized are clearly invalidated by Behre (1983) and need no following.

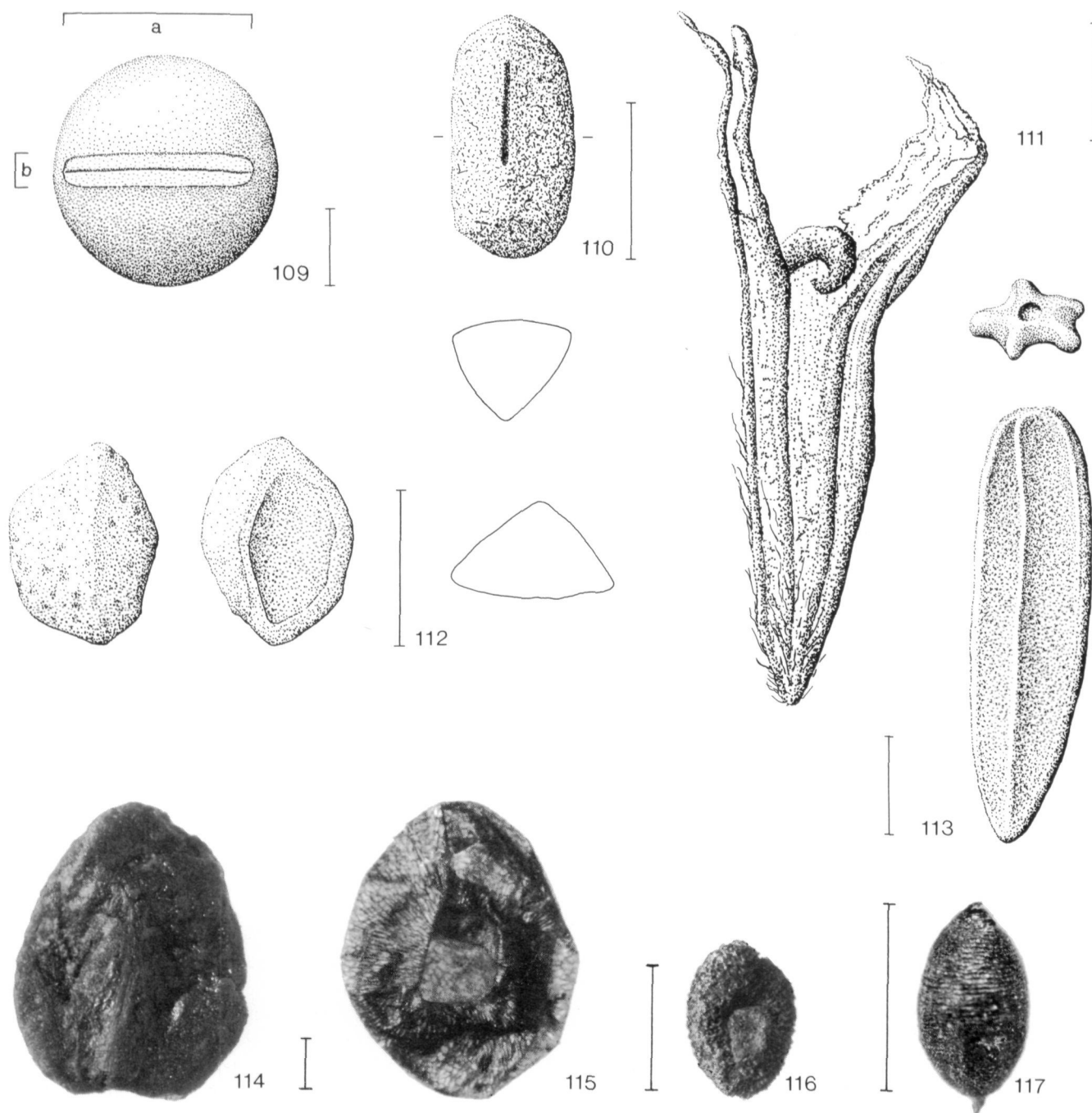


Fig. 109 *Vicia* spec. Measurements of dimensions A and B (12x)

Fig. 110 *Lysimachia thyrsiflora* (25x). Sp.17-34:337.

Fig. 111 Calyx of *Limonium vulgare* (15x), containing seed of fig. 110.

Fig. 112 *Lysimachia vulgaris* (25x). Nh.09-89:3009.

Fig. 113 *Limonium vulgare* (15x). Ro.08-52:1069.

Fig. 114 *Crataegus laevigata* (8x). Sp.17-34:337.

Fig. 115 *Galium aparine* (8x). Sp.17-35:612.

Fig. 116 *Galium saxatile* (20x). Sp.17-35:612.

Fig. 117 *Euphrasia/Odontites* (30x). Rock. 10-1-4.

Scale units equal 1 mm.

Rosa spec.

Rock.10-2-56 (n=1): 4.67 × 2.56 × 1.54 mm

Sp.17-34:279 (n=1): 4.03 × 2.43 mm

Sp.17-34:306 (n=2): 4.86 × 2.17 × ?; 4.93 × 3.20 × 2.24 mm

Rosa fruitstones are irregularly angular with a conspicuous groove on the longitudinal axis. Identification below the genus-level is not possible because of the large variation in the size of the different species.

Rubiaceae*Galium aparine*

Sp.17-35:612 (n=25): largest diameter: 3.54 (3.17-4.16) mm

The uncarbonized fruits are completely flattened, which causes the large diameters. The round opening is clearly discernible (see fig. 115). The surface consists of elongated cells. The size and surface pattern exclude other *Galium* species (Lange 1979).

Galium saxatile (= *hercynicum*).

Sp.17-35:612 (n=9): 1.14 (0.90-1.25) × 0.77 (0.51-0.90) mm

The fruits are elliptical in outline. The surface is densely covered with fine spines. On the ventral side a large, sunken hilum is present, which is symmetrically placed on the longitudinal axis of the fruit (see fig. 116). Corroded *Epilobium hirsutum*-type fruits may at first glance resemble these small *Galium* seeds, the hilum, however, is completely different. The only *Galium* species with equally small fruits is *G. uliginosum*, but this species has a more verrucate surface (cf. fig. 865 and 870 in Beijerinck 1947). Katz *et al.* (1965, pl. 81, fig. 28 and 29) illustrate a spiny *Galium* fruit as *G. uliginosum*. Our reference collection is in agreement with Beijerinck's illustration and the subfossil specimens are in consequence attributed to *G. saxatile*. To my knowledge, this species has not been described in palaeobotanical studies before.

Scrophulariaceae*Euphrasia/Odontites spec.*

Uncarbonized seeds are characterized by a scalariform surface pattern and a broad keel on one side. In a carbonized state both these marked features disappear. What remains is the "inner" seed, with pointed ends and on the surface a fine transverse striation (cf. Van Zeist/ Palfenier-Vegter 1983; fig. 117). Both genera produce very similar seeds, which cannot be separated.

Pedicularis palustris

Sp.17-35:598 (n=3): 1.85 (1.61-2.02) × 1.06 (0.96-1.12) mm

The obovate seed of this species has a distinct, elongated reticulate pattern and a longitudinal groove on the ventral side.

Veronica beccabunga-type

Sp.17-34:266 (n=25): 0.62 (0.45-0.72) × 0.45 (0.37-0.56) mm

The small seeds have a conspicuous hilum about 1/3 from the base. The transparent seeds show a fine surface pattern. According to Conolly *et al.* (1950) and Jacquat (1988), *V. anagallis-aquatica* has even smaller seeds than *V. beccabunga*, the size range of which corresponds well to the present ones. Conolly *et al.* also report that *V. catenata* (= *aquatica*) is as small as *V. anagallis-aquatica*, but in our reference collection the seeds have the same size as *V. beccabunga*. Bakels (1981) mentioned that *V. longifolia* and *V. scutellata* are similar in size to *V. beccabunga*. The seeds of these two species are, however, substantially larger (ca. 1 mm), and in Oss-IJsselstraat we are probably dealing with them, considering their sizes of 0.9 × 0.7 and 1.2 × 0.8 mm.

In conclusion, it is *V. beccabunga* (or probably *V. catenata*) that is involved here. They are included in the *Veronica beccabunga*-type. The large amounts recorded in Spijkenisse 17-34 are exceptional. They were mainly present in the residue on the 1/4 mm sieve, which may partly explain their near absence in palaeobotanical literature.

Solanum dulcamara

Sp.17-35:600 (n=2): 2.22-2.42 × 1.79-2.14 mm

Nh.09-89:3035(n=4): 2.38 (2.24-2.56) × 2.02 (1.86-2.14) mm

Solanum nigrum

Sp.17-35:612 (n=16): 1.90 (1.60-2.05) × 1.51 (1.22-1.66) mm

Nh.09-89:3035(n=15): 1.88 (1.66-2.14) × 1.48 (1.25-1.73) mm

The seeds of these species can in most cases be distinguished by their size and shape. *S. dulcamara* is larger and more rounded than the smaller *S. nigrum*, which has a pointed end. In practice, large seeds with more or less pointed ends do occur. Villaret-von Rochow (1967) already noticed that these characteristics show an overlap. Behre (1976c) in this respect observed that it is not always possible to distinguish the two species. In the present study pointed seeds hardly ever exceeded 2 mm in length, they were attributed to *S. nigrum*. Seeds well over 2 mm were identified as *S. dulcamara*, although some were rather elongated. Doubtful specimens are always attributed to the species already present in the sample concerned, or listed as *Solanum spec.*, if no seeds

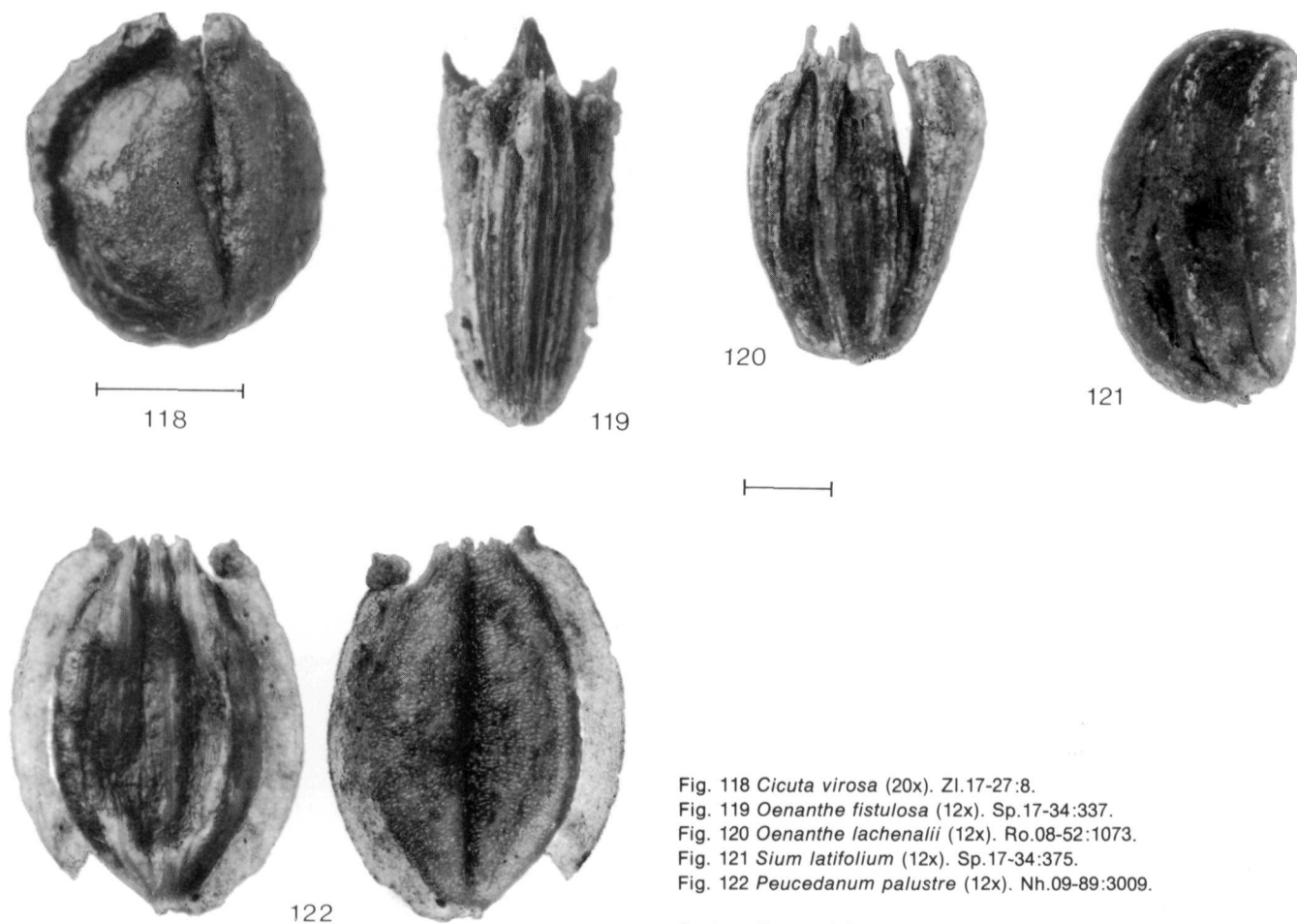


Fig. 118 *Cicuta virosa* (20x). Zl.17-27:8.
 Fig. 119 *Oenanthe fistulosa* (12x). Sp.17-34:337.
 Fig. 120 *Oenanthe lachenalii* (12x). Ro.08-52:1073.
 Fig. 121 *Sium latifolium* (12x). Sp.17-34:375.
 Fig. 122 *Peucedanum palustre* (12x). Nh.09-89:3009.

Scale units equal 1 mm.

in that sample could be identified with certainty. *Solanum nigrum* is the most common of these species in the present study.

Umbelliferae

Angelica sylvestris

Sp.17-34:279 (n=1): 3.81 × 3.30 mm

The fruits (mericarps) are broadly winged and have three high ribs on the dorsal side. The two ventral wings do not touch each other, whereas they do so in *Peucedanum palustre*. The latter species is shown in figure 122.

Cicuta virosa

Zl.17-27:8 (n=2): 2.24 × 1.66 mm; 2.46 × 2.30 mm

The fruits are semi-circular with a flat ventral side. They are unwinged. The presence of one flattened side and broad ribs

point to an Umbelliferae species, the shape is characteristic of *Cicuta virosa* (see fig. 118).

Oenanthe fistulosa

Sp.17-35:598 (n=25): 3.40 (2.88-4.00) × 1.80 (1.44-2.24) mm

The fruits are characteristic, with large lateral ribs of spongy tissue and three projections on the top of the fruits (see fig. 119). The similarly trapezoidal fruits of *O. lachenalii* are much smaller than those of *O. fistulosa* (cf. Van Zeist 1974).

Oenanthe lachenalii

Nh.09-89:3037 (n=10): 2.36 (2.14-2.67) × 1.42 (1.27-1.83) mm.

The small size and the trapezoidal shape of the fruits are typical (see fig. 120). When the spongy tissue has corroded,

which was often the case, identification presented many more difficulties.

Sium latifolium

Sp.17-34:375 (n=8): 2.66 (2.34-3.20) × 1.55 (1.18-2.08) mm

The fruits are unwinged and slightly concave on the ventral side. The dorsal side is more convex, which results in a shape resembling a banana (see *fig. 121*). The fruits have five light ribs (see also Körber-Grohne 1967).

Umbelliferae Indet.

Heavily corroded umbelliferous fruits were quite often found. If the ribs and wings are absent, nearly all species become very similar. They are therefore listed under this taxon.

Violaceae

Viola palustris-type

Sp.17-35:612 (n=4): 1.77 (1.68-1.91) × 1.13 (1.05-1.17) mm

On the basis of lengths and widths of recent *Viola* seeds, Jacomet *et al.* (1989: 291) distinguished three groups. The group with the smallest seeds, with a length of 1.5-1.8 mm, includes *Viola arvensis*, *V. tricolor*, *V. rupestris*, *V. palustris*, *V. canina* and *V. montana*. The first two species seem to be too small for the present material, the remaining four species seem indistinguishable at present. *Viola palustris*, the most likely species concerned, has been chosen to name this type.

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summary

The investigations presented here concern the habitation in an area to the south of the Meuse estuary during the Iron Age and the Roman Period. The area studied comprises the present-day Dutch islands Voorne and Putten (province of Zuid-Holland). These islands will hereafter be referred to as Voorne-Putten.

From a botanical point of view, the investigations concern the reconstruction of former landscapes, the environmental changes that occurred and the agricultural possibilities that these landscapes offered. Furthermore, the possible effects of the incorporation of Voorne-Putten into the Roman Empire were studied.

Before the start of the investigations, it had been demonstrated that settlements during both the Early and Middle Iron Age (c. 625-225 BC) were built on peaty soils in the area of the present-day Bernisse. There appears to be a hiatus in the habitation between those two periods. Man lived in usually three-aisled farms which housed livestock as well. The settlements, consisting of single farms, were situated in the vicinity of creeks in the landscape.

Geological investigations had revealed that considerable environmental changes took place after the Middle Iron Age. Marine inundations during the so-called Dunkirk I transgression phase caused sedimentation of clastic sediments in large parts of the area, and the present-day Bernisse was formed. The inhabitation during the Late Iron Age (c. 225-50 BC) was concentrated in settlements on these clayey sediments. On western Voorne, some settlements were established on raised bog cushions. The Dunkirk I sediments on western Voorne were deposited on top of the Late Iron Age remains. These Dunkirk sediments are therefore asynchronous, even within such a small area as Voorne-Putten. The habitation during the Roman Period (c. 50-275 AD) mainly occurred again on the clayey sediments, but also on peat in the vicinity of these clayey soils.

Palynological investigations of peaty sediments demonstrated the Early and Middle Iron Age inhabitants to have settled on eutrophic peat where the vegetation was dominated by reed. The landscape surrounding the farms was open, with only few trees. During the Middle Iron Age, the shrub bog myrtle could spread over large parts of the area,

which can be attributed to oxidation and mineralisation of the peaty soils. These processes will have been caused by an increased drainage of the peat as a result of the extensive system of gullies formed by the transgressive sea.

Along the Meuse, several kilometres away from the settlements, lay elevated levees, covered with trees characteristic of river valleys. Oak and elm grew on the higher parts, alder and willow on the more frequently inundated, lower parts. During the Early Iron Age inhabitation, human activities caused deforestation of the levees. The forests recovered during a hiatus between the Early and Middle Iron Age inhabitation, but during the latter renewed deforestation took place.

The Dunkirk I transgression phase caused peat growth to come to an end in virtually the whole area. Some renewed peat growth occurred just after the end of the Roman inhabitation. Reconstruction of the landscape during the Late Iron Age and the Roman Period is therefore not possible. Near Rockanje, local peat growth did occur between the Late Iron Age and the Roman Period. However, the peat contained a large proportion of clay and pollen originating from elsewhere. Therefore, the pollen does not necessarily provide information on the investigated area itself. The peat near Heenvliet, studied by the *Rijks Geologische Dienst*, also revealed growth continuing well into the Roman Period.

Investigations of the wood remains demonstrated that elm and sycamore were preferred for the heavier, roof-supporting construction elements in two Early Iron Age farms. By today's standards, these trees provide relatively durable timber. For the other parts of the constructions, alder was commonly used, whereas willow was preferred for wickerwork. These two trees provide the least durable woods. In a third Early Iron Age farm, only alder and one single willow were used. Remarkable is the absence of oak, because of its durability highly suitable for critical construction elements, despite the fact that this tree had been felled on a large scale, as the pollen diagrams showed.

Alder and willow are the dominant trees found in a Middle Iron Age farm. However, only a long wall of a farm could be excavated on this site. The only sycamore found

was in one of the scarce roof supports. The role of more durable trees in this period is therefore difficult to assess, but will have been smaller than in the Early Iron Age.

Rockanje 08-52 is the only excavated Late Iron Age site to date. The wood of this site has not yet been fully investigated.

During the Roman Period, four farms were built, one above the other, near Nieuwenhoorn. In the oldest farm, elm and sycamore were selected for the roof-supporting elements, in the following three phases oak was used. The large quantities of oak made dendrochronological research possible. This showed that the different constructions were built in the years 57 AD, 62 AD, 86 AD and 107 AD respectively. The trees used were probably obtained locally. The trees used in the last building phase had grown more irregularly, indicating that the supply of oak was probably running short.

In view of the good correlations of the yearring patterns with those of oaks from mineral soils and no correlation with oaks from wet environments, it can be deduced that the oaks used in Nieuwenhoorn were obtained from mineral soils. The levees along the Meuse or the Older Dunes may well have supplied these oaks.

In the native Roman settlement near Rockanje, only alder and ash could be demonstrated, the latter species being preferred for crucial construction elements. A granary found on this site had sixteen alder posts, each with a diameter of 25 cm or more. The wood remains in the third Roman settlement, Simonshaven, was only fragmentarily preserved due to the height above the water table. The high proportion of oak recovered on this site may be biased due to the greater resistance of oak against decomposition.

In most cases, the remains of the investigated former settlements ended up under the water table during or after inhabitation. As a result of the absence of oxygen, organic matter was not decomposed. As well as wood, an abundance of seeds and other plant remains was preserved in an uncarbonized state.

The investigations of the many waterlogged as well as the less common carbonized botanical macroremains has yielded numerous data that support and supplement the results of the palynological studies. The location of the Early and Middle Iron Age sites in reed swamps is apparent again. The Late Iron Age inhabitants near Rockanje and the Roman ones near Nieuwenhoorn had settled on a raised bog. The common presence of bog myrtle points to drainage and oxidation. This will have been an important factor influencing man's decision to inhabit the formerly wet peat. The rapid deposition of material on the Nieuwenhoorn site probably compensated subsidence due to compaction.

The Roman site near Rockanje was located on a higher part of a salt marsh, where fresh water occurred during

greater parts of the year. The sea will have been near the site only sporadically. Low dwelling mounds were raised to protect the settlement against inundations.

A number of cultivated crop plants and deliberately gathered plants occurred among the botanical macroremains. The cereals emmer wheat and four-row barley occur in nearly all Iron Age sites, as well as crops with oil-rich seeds, linseed and/or gold of pleasure. Two Early Iron Age sites differ considerably in this respect. No carbonized or uncarbonized remains of crop plants were found in Rotterdam-Hartelkanaal. The only cereal remains from this site are impressions of grains on pottery.

Barley was absent in the Early Iron Age site of Spijkenisse 17-30. Next to emmer wheat, a limited number of broomcorn millet grains occur. The oil-rich crops linseed and gold of pleasure are absent as well, while rape seed does occur. The spectrum of crop plants from the third Early Iron Age site, Spijkenisse 17-35, is more like that of the Middle and Late Iron Age sites, with barley, linseed and gold of pleasure.

The crops found in the native Roman settlement of Nieuwenhoorn are dominated by barley, whereas emmer wheat, linseed and gold of pleasure play only a minor role. In addition, some Celtic beans were found here. In the settlement of Rockanje, four-row barley is even more important and only very few wheat remains occurred.

Striking is the fact that all crop weeds found are characteristic of arable fields sown in spring (so-called summercrop weeds). Weeds that characterize wintercrops are completely absent. The absence of wintercrop weeds and deforestation of the levees in the Iron Age, not due to the use of these trees for building purposes may indicate that the levees were cleared for agriculture. The fertility of the soils is guaranteed as these levees are frequently inundated in winter, making the growth of wintercrops impossible. After sedimentation of Dunkirk I deposits, these clastic soils created a large extension to the potentially arable area. In wintercrops on heavy clayey soils, as occurred near Roman Rockanje, only summercrop weeds develop due to the richness of the soil. Sowing of wintercrops in Rockanje therefore cannot be ruled out on the basis of the absence of wintercrop weeds. However, experiments in present-day salt marshes have demonstrated that the risk of inundations is high in winter, which also renders the cultivation of wintercrops on these soils unlikely.

Cluster analyses revealed that samples obtained from one single site resemble each other more closely than samples from different sites. Salinity is shown to be the ecological key factor for the greater intersite variation.

The cluster analysis of crop plants only resulted in a much higher similarity between the different sites. The similarity between the sites was even higher in the cluster analysis of crop weeds and of all carbonized macroremains.

Conspicuous differences occur in the proportion of crop weeds and plants of grasslands. In the Early and Middle Iron Age sites grassland plants are much more common and an increase of crop weeds can be observed over time. In the Roman site of Rockanje, the crop weeds are clearly dominant. It is assumed that a relationship exists between the share of grassland plants and the importance of stockbreeding. In settlements, seeds of crop weeds are systematically over-represented in comparison to seeds of grassland plants, so the relationship between the share of grassland plants and the importance of stockbreeding is not one to one.

The share of wild plants deliberately gathered for food is small. Only a few seeds of sloe, blackberry species, rose and elder could be found. Mannagrass was also gathered during the Middle Iron Age, as appears from a concentration of seeds in a hearth.

Dr. W. Prummel and Drs. P.J. van Mensch investigated faunal remains from Iron Age and Roman sites on Voorne-Putten. The preservation of bone, in contrast to botanical remains, is rather poor due to the peaty sediments. The individual sites yielded too few data to provide conclusive results. Therefore, the faunal remains have been grouped for each period.

The remains of hunted animals are negligible in all three phases of the Iron Age as well as in the Roman Period. Only one Late Iron Age site yielded large amounts of sturgeon remains. The majority of bone remains comes from domestic animals. Within these domesticates, cattle was by far the most important, especially during the Iron Age. Whether the production of milk was important cannot be ascertained well. Sheep/goat remains were the next most important. When the remains could be attributed to one of these two species, they belonged to sheep.

Pig comes third in importance among the faunal remains. Bones of dogs and horses were also found, but they were not kept for meat, as the bones lack butchering marks.

Faunal remains from Roman sites were studied less extensively. An increase in the importance of sheep/goat is apparent, but this might be due to better preservation conditions. Cattle remains, however, the dominant animal for slaughter.

In the reconstruction of the agricultural economies, an important question is whether the inhabitants were self-supporting, i.e. whether they could produce enough to fulfill their own requirements. It is relevant to know the demands are of the crops and domesticates found. Apart from such data, which are mainly based on factual criteria, palaeobotanical data can be used to make statements on local production versus import of certain crops. The cereals barley and millet could probably have been cultivated on the peaty soils

around the Early and Middle Iron Age settlements, but not emmer wheat. The various crops with oil-rich seeds could not have been grown on peat, with possible exception of gold of pleasure. In this species, a distinct discrepancy arises between palaeobotanical and recent data. Experimental cultivation of the Iron Age crops on peaty soils could offer an important contribution to our knowledge. This does apply to cereals as well.

Botanical macroremains may provide data about local cultivation of a crop versus import. The crop-processing by-products ("waste") provide relevant information in case of barley, linseed and gold of pleasure. Prerequisite is the investigation of a sufficient number of samples from as many different context-types as possible.

In case of emmer wheat, it must be noted that by-products, which according to ethnographic research point to local cultivation, i.e. larger stem fragments as well as culm nodes, are very rarely found in palaeobotanical investigations. As chaff remains of emmer (glumes) can be found on importing as well as producing sites, we can draw no conclusion as to the local production or import of emmer.

It must be assumed that domestic animals were kept near the farms. This assumption is supported by the regular occurrence of partitions (bays) as well as by the thick layers of dung in farmhouses. The most important meat supplier, cattle, could have been grazed in the reed vegetations around the settlements. During the Late Iron Age and the Roman Period, such vegetation types will have been present in the vicinity of the settlements as well. Recent investigations in the Dutch wetland area "Oostvaardersplassen" have shown that cattle can feed on reed. Grazing by cattle results in an increase of vegetation types with smaller herbs that can be digested by sheep as well. The elliptical droppings with virtually nothing but remains of the locally growing bog myrtle were most probably produced by goats.

The three excavated Early Iron Age farms show a remarkable trend. In Rotterdam-Hartelkanaal, the wood for construction purposes is of a poor quality and crops as well as crop weeds are absent in the samples for macroremains. In Spijkenisse 17-30, more durable timber was used, but the assortment of crop plants, with millet and rape seeds, differs considerably from the third Early Iron Age site, Spijkenisse 17-35 and the Middle Iron Age sites. Furthermore, botanical macroremains which indicate the local cultivation of a crop, are absent in Spijkenisse 17-30, and so are ecologically restricted crop weeds. In Spijkenisse 17-35, barley, linseed and gold of pleasure were cultivated as well as threshed by the Early Iron Age inhabitants. Besides, some specific summer-crop weeds were found on this site.

The results of the botanical investigations of these three settlements fit well into a model developed by Brandt *et al.* (1984) to explain Iron Age habitation of the peaty area in

the Assendelver Polders. These Polders are situated in another Dutch estuary, viz. that of the Oer-IJ. According to this model, a formerly uninhabited peaty area is first explored during short visits. Subsequently, the area is used for cattle-grazing during summer. The inhabitation is non-permanent and no arable farming is practised. This phase may be represented by the site of Rotterdam-Hartelkanaal. In the next phase, man settles permanently in the area, but only to practise stockbreeding. Arable products are obtained through exchange with relatives elsewhere. Spijkenisse 17-30 could probably represent this phase. Finally, arable farming would be practised by the peat dwellers themselves, thereby returning to a mainly self-supporting economy. This phase is most probably represented by the site of Spijkenisse 17-35.

The inhabitants of all Middle Iron Age sites studied seem to have been mixed arable and pastoral farmers. A hiatus in inhabitation between the Early and the Middle Iron Age does not seem to have been followed by a step-wise colonization as described above. Provisionally it can be concluded that the knowledge of the agricultural potential of the area was retained during a hiatus in habitation of ca. one century, although this needs to be confirmed by the study of more Middle Iron Age sites.

The find of a concentration of carbonized seeds of mannagrass in combination with several carbonized crop plants in a hearth of the Middle Iron Age site of Spijkenisse 17-34 is an indication of the use of this grass as food. Written sources attest the gathering of mannagrass for consumption until the 18th century. During the Middle Iron Age, the energy requirements near Spijkenisse could apparently not be completely satisfied by cereals.

The Late Iron Age follows the Middle Iron Age without an hiatus. During the Late Iron Age, a self-supporting food production existed. The environment did no longer provide limitations because of the clayey Dunkirk I deposits around the Bernisse.

During the Roman Period a farm near Nieuwenhoorn existed in the 1st and early 2nd centuries of our era. Wheat is of minor importance here, and so are linseed and gold of pleasure. Barley is the dominant crop, Celtic beans were cultivated as well. Near Rockanje, situated in a salt marsh environment during the 2nd and 3rd centuries AD, almost exclusively barley was grown. Although gold of pleasure and Celtic bean can be cultivated successfully in such an environment, do these crops lack completely. The arable farming practiced in Rockanje seems to have been specialized.

After assessing which crops were probably grown by the inhabitants of the sites and which animals contributed to the food production, an attempt was made to assess whether man could completely fulfill his own requirements for food.

Based on the number of stalls in farms, estimates of the meat- and milk production were made. Subsequently, the

share of the total calorific and protein requirements provided by these animal products were calculated. For the Iron Age, hypothetical farms with six and ten stalls were chosen. For these farms, the number of inhabitants were alternatively estimated at four and six. The lower number is based on the area of the living quarters of the farms and 10 m² per person is assumed. The higher number is often quoted in relevant literature.

On a farm with six stalls, animal products can provide 47-67% of the energy requirements of a hypothetical family of four persons. The remaining calories will mainly have been supplied by cereals. In that case, the protein requirements will also have been fulfilled. If this farm with six stalls was inhabited by six persons plus a baby, 31-44% of the energy required would be covered by animal products. The amount of grain needed to provide the balance could have been obtained from three ha of arable land.

On the hypothetical farm with ten stalls, 58-84% of the energy requirements of four inhabitants could be obtained from animal products. Six inhabitants plus a baby could have obtained 38-54% of the needed calories through animal products. In this case, a maximum of 2.5 ha of land under cereals cultivation would be needed.

The inhabitants of Rotterdam-Hartelkanaal, with six stalls, had to consume vegetable products to meet their demands for energy. The import of grain suggested in the model of Brandt *et al.* obliged the inhabitants to maintain contacts with a community that produced grain in excess of its own needs (surplus). The inhabitants of Spijkenisse 17-30 would have had to import grain, in this case emmer, or they could have grown it themselves on the levees along the Meuse. Crop remains proving local production or import are absent in Spijkenisse 17-30, so it is not possible to decide between the above-mentioned alternatives.

In the case of Spijkenisse 17-35 and, more markedly, in the Middle Iron Age sites, evidence for cultivation of crops by the inhabitants was found, they were thus essentially self-supporting. Since barley is the only cereal found in the Early Iron Age samples of Spijkenisse 17-35, local cultivation on peat cannot be excluded. For emmer, which occurs regularly in the Middle Iron Age sites, cultivation on peat is highly improbable. As these settlements are as far removed from the levees along the Meuse as Spijkenisse 17-30, viz. several kilometres, this distance probably did not pose unsurpassable problems. In present-day, non-mechanized societies, this distance can be bridged as well. The fact that all Early and Middle Iron Age sites were situated along gullies will have been of great importance for the bulk-transport of grain.

During the Late Iron Age, arable production could take place close to the settlements. The sandy to clayey Dunkirk I deposits around the Bernisse could have supported dozens of self-sufficient Iron Age farms.

The number of contemporary farms was estimated on the

basis of the known number of sites and the estimated duration of each phase. The number of inhabitants during all phases of the Iron Age was so small, that contacts with other groups were necessary, despite a self-supporting food production. The number of inhabitants was too small to maintain an independent population. Based on similarities in pottery, inhabitants of the Older Dunes and probably of the levees along the Meuse were involved here.

The clear partitions of the Iron Age byres are not discernible in the native Roman farms. On the basis of the sizes of the farms and the thickness of the layers of dung in the heightening material, especially in Nieuwenhoorn, it can be concluded that pastoralism was an important economic activity. The number of inhabitants of the farms probably exceeded that of the Iron Age, six to eight persons per farm are assumed here. The sizes of the farms seem to indicate that at least as many animals could be housed as in the Iron Age farm with ten stalls. In case of six inhabitants, 38-54% of the calorific requirements can thus be provided by animal products again, for eight inhabitants this share may have been 25-36%.

The granaries found in the native Roman settlements near Rockanje and Simonshaven were so large that they could easily have stored grain far in excess of the yearly cereal requirements of a family. More than 7000 kg of barley could have been stored if a wall of 30-35 cm high was present on the floor of a granary. It is assumed here that these stockpiles did not serve to compensate for harvests failures in several successive years, but that it concerns a surplus to be supplied to others.

Calculations of the amount of land required in the various models reveal that during the Iron Age enough herbaceous reed vegetations existed for both pastures and hay-making. The levees along the Meuse may have provided arable land for dozens of self-supporting Iron Age farms. The highest estimate for the number of contemporary Iron Age farms in the peaty area is ten. This is far below the area's carrying capacity for agriculture. During the Late Iron Age the clayey area around the Bernisse could have supported up to a hundred contemporary settlements.

A much larger area of cereal cultivation is required in the Roman Period, to produce the surpluses calculated. If a fallow is cautiously estimated for every other year, an area of ca. 29-34 ha is required to fill one granary. The area around the Bernisse may have supported 21-25 contemporaneous farms, provided that livestock was grazed in peaty areas. It is estimated that 30 contemporaneous native Roman farms existed in this area. All farms combined cannot have produced the amount of grain needed to fill granaries the size of those of Simonshaven or Rockanje. The far larger clay cover on western Voorne will not have limited production, the more so since probably fewer settlements were located there.

Subsequently, the amount of labour required in the various models has been estimated to ascertain whether this would have been a limiting factor. The cutting of reed for winterfodder may have taken one person one month of labour. This time may well have been available after the harvesting of cereals and other crops. As far as the cereals are concerned, the method of sowing is of primary importance. It is assumed here, that the labour-intensive method of sowing in rows was practiced during the Iron Age. In that case, a maximum of 3 ha was required to obtain the amount of grain calculated above. The critical point in the Iron Age grain supply will have been harvesting, which had to be completed within one month. Harvesting 3 ha takes ca. 60 working days, so two persons were required to harvest cereals in just one month.

These calculations have important implications for the model of colonization of peaty areas. The 3 ha which can be harvested at a maximum can meet the demands of a family, which relies primarily on pastoral farming. Severe complications arise if it is assumed that the inhabitants of Rotterdam-Hartelkanaal and Spijkenisse 17-30 obtained their cereals from relatives specialising in arable farming. The latter not only had to produce the cereals they required for themselves, but also for the pastoral peat dwellers. This implies that they had to cultivate at least 6 ha of arable land. This can only have been possible if they were assisted by the peat inhabitants during critical periods such as the harvest.

The difference with the alternative situation, in which the inhabitants of the peaty area had their own arable fields on the levees at several kilometres distance, becomes rather small. With such a marginal difference, the economy of the peat dwellers may well have been autonomous or relied on an exchange with assistance in harvesting.

Calculations for the Roman Period revealed that 14-17 ha of grain sown in rows was required to fill a granary. Harvesting such an area in one month would have required ten persons, while the native Roman farms probably had six to eight inhabitants. Sowing in rows was therefore impossible. The alternative, broadcast sowing, would require 150-180 working days, as in that case the same gross-yield is obtained from a smaller area. With this method of sowing, five to six people would be needed, which is just feasible. A larger part of the grain stored in the granaries must be reserved for sowing the following year. The surplus may have been supplied to the Roman army, enough to feed eleven soldiers. This amount of grain could have been produced by a household of eight persons.

It is assumed that the transition from the Iron Age to the Roman Period had considerable implications for the autochthonous inhabitants of the area occupied. Groenman-van Waateringe distinguished several phases of development in

the agricultural economy during Roman times. During the occupation campaigns, food will have been supplied from areas occupied earlier. The local production could not have met the demands, quantitatively nor qualitatively. Especially the fact that the legions would mainly consume wheat, and not barley, is stressed by Groenman-van Waateringe. The second phase is the adjustment of the local production to the military demands. This phase is thought to have lasted until the first part of the 2nd century AD. The last phase, one of stabilisation, lasted until the second part of the 3rd century. The production would thereafter decline due to soil exhaustion and erosion. Grain for the Roman army is imported from Great-Britain by ship.

The two native Roman settlements on Voorne-Putten can be viewed in this light. Both Nieuwenhoorn, dating from the 1st and the start of the 2nd century and Rockanje, dating from the second half of the 2nd and the first half of the 3rd century, appear to have produced mainly barley. Particularly in the case of Rockanje a specialisation in this crop seems to have occurred. A change to wheat cannot be demonstrated. Moreover, in the saline environment around Rockanje, wheat could not have been grown. Alternatively,

the surplus of barley was not consumed by the Roman soldiers but by their horses. Horses were numerous in the Roman army, as can be deduced from the presence of cavalry divisions in the Roman *castella*.

Quantitative changes did occur after the transition from the Iron Age to the Roman Period, as is clearly evidenced by the large granaries with a storage capacity far above the requirements of a single household. The diversification of houseplans and the few crop species found point to specialization in agricultural production. Qualitative changes, however, are not discernible.

The investigations were only possible due to the excellent preservation of organic matter on Voorne-Putten. This preservation does not occur in the presence of oxygen as the remains decompose. In that case, only carbonized material will endure the ravages of time. Oxidation, due to artificial lowering of the water table for agrarian purposes, threatens to have a devastating and irreversible effect on the remains that have been preserved for thousands of years, and thereby on the possibilities for meaningful archaeological and ecological investigations.

samenvatting

Het hier gepresenteerde onderzoek richt zich op de bewoning van het gebied ten zuiden van het Maas-estuarium gedurende de IJzertijd en de Romeinse Tijd. De huidige Zuidhollandse eilanden Voorne en Putten vormden het onderzoeksgebied. In het vervolg worden deze eilanden kortweg aangeduid met Voorne-Putten. Vanuit een botanisch perspectief werd onderzocht hoe het landschap eruit zag, of zich landschappelijke veranderingen voordeden, welke agrarische mogelijkheden deze landschappen boden en wat het eventuele gevolg was van de inlijving van het gebied in het Romeinse Rijk.

Door middel van archeologische opgravingen was reeds vastgesteld dat de bewoning in de Vroege en Midden-IJzertijd (van ca. 625 tot ca. 225 v. Chr.) zich had gevestigd in het veengebied rond de huidige Bernisse. Er is een bewoningshaat tussen de Vroege en Midden-IJzertijd. Men woonde in drieschepige woon-stalhuizen. Het vee was onder hetzelfde dak gehuisvest als de mensen. De nederzettingen, bestaande uit geïsoleerde boerderijen, lagen in de onmiddellijke nabijheid van kreken in het landschap.

Uit geologisch onderzoek bleek, dat het landschap na de Midden-IJzertijd sterk veranderde. Door inbraken van de zee tijdens de zogenaamde Duinkerke I transgressie-fase werd op aanzienlijke schaal klei afgezet. Tevens werd de Bernisse, zoals we die nu kennen, gevormd. De bewoning in de Late IJzertijd (ca. 225 tot ca. 50 v. Chr.) rond de Bernisse concentreerde zich op deze klei-afzettingen. In het westelijke deel van Voorne woonde men op een hoogveen-kussen. Op westelijk Voorne zijn de Duinkerke I afzettingen pas gevormd na de Late-IJzertijd-bewoning aldaar, wat de asynchroniteit van deze afzettingen, zelfs in een beperkt gebied als Voorne-Putten, demonstreert. De bewoning in de Romeinse Tijd (ca. 50 tot ca. 275 AD) is eveneens vooral in de kleigebieden gelocaliseerd, maar ook het veen in de nabijheid van de kleidekken werd bewoond.

Door middel van stuifmeel-onderzoek (palynologie) van veen-afzettingen kon in het huidige onderzoek worden vastgesteld dat de bewoners zich tijdens de Vroege en Midden-IJzertijd hadden gevestigd op voedselrijk (eutroof) veen; de begroeiing werd gedomineerd door riet. Het landschap rond de nederzettingen was zeer open; er was nauwelijks boomgroei. Ten tijde van de Midden-IJzertijd-bewoning kon de

gagelstruik zich sterk uitbreiden, wat toegeschreven kan worden aan oxydatie en mineralisatie van het veen. Dit zal het resultaat zijn geweest van verbeterde ontwatering van het veen, wat veroorzaakt kan zijn door de vorming van een uitgebreid stelsel van geulen ten gevolge van de toenemende invloed van de zee.

Verderweg van de bewoning, langs de oevers van de Maas, lagen oeverwallen, begroeid met karakteristieke boomsoorten van ooibossen. Eik en iep groeiden in de ooibossen op de drogere delen, els en wilg op de nattere plaatsen. Tijdens de bewoning van de Vroege IJzertijd trad op grote schaal ontbossing van de oeverwallen op door houtkap door de mens. Tijdens het hiaat in de bewoning tussen de Vroege en de Midden-IJzertijd kon de ooibos-vegetatie zich enigszins herstellen, maar tijdens de Midden-IJzertijd werd opnieuw op grote schaal gekapt.

Doordat als gevolg van de Duinkerke I transgressie-fase het veen ontwaterde, kwam de veengroei in vrijwel het gehele gebied tot stilstand. Op een enkele uitzondering na trad veenvorming pas weer op vlak na het verdwijnen van de Romeinse bewoning in het gebied. Hierdoor levert palynologisch onderzoek geen informatie op over het landschap in de Late IJzertijd en de Romeinse Tijd. Veenlagen, die onontbeerlijk zijn voor de conservering van stuifmeel (pollen) zijn immers niet of nauwelijks meer voorhanden. Weliswaar bevatten klei-afzettingen eveneens pollen, maar dit kan met water van ver uit het achterland zijn aangevoerd. Dit pollen levert niet altijd informatie over het gebied van onderzoek zelf. Eén van de weinige bekende veenpakketten dat tussen de Late IJzertijd en de Romeinse Tijd werd gevormd op Voorne-Putten ligt bij Rockanje. Dit veen bevatte zoveel klei en tevens pollen dat via het water van ver moet zijn aangevoerd, dat er geen betrouwbaar beeld van het landschap mee kon worden verkregen. Ook het door de Rijks Geologische Dienst onderzochte veen nabij Heenvliet vertoonde veengroei tot in de Romeinse Tijd.

Bij onderzoek van het bouw hout kon in twee Vroege-IJzertijd-boerderijen bij Spijkenisse geconstateerd worden, dat bij voorkeur iep en esdoorn voor de zwaardere, dakdragende constructie-elementen zijn toegepast. Naar huidige maatstaven zijn dit redelijk duurzame houtsoorten. Voor het overige constructie-hout was vooral veel elzhout gebruikt

en wilg voor het vlechtwerk. Dit zijn de minst duurzame inheemse houtsoorten. In de derde hier onderzochte Vroege-IJzertijd-boerderij, Rotterdam-Hartelkanaal, blijkt vrijwel uitsluitend els en eenmaal wilg te zijn gebruikt. Opvallend is dat eikehout nagenoeg ontbreekt in deze drie boerderijen, terwijl het pollen-onderzoek wel een grootschalige kap van eik in de Vroege IJzertijd aangaf.

De enige Midden-IJzertijd-boerderij waarvan het hout kon worden onderzocht, wederom bij Spijkenisse, leverde ook hoofdzakelijk els en wilg op. Op deze vindplaats kon echter vrijwel uitsluitend een lange wand van de boerderij worden opgegraven. De enige aangetroffen esdoorn was één van de weinige resterende middenstaanders. De rol van duurzame houtsoorten is niet goed te bepalen, maar zal kleiner zijn geweest dan in de twee Vroege-IJzertijd-boerderijen bij Spijkenisse.

Het houtonderzoek van de Late-IJzertijd-boerderij van Rockanje 08-52 is op dit moment nog niet afgerond.

Bij Nieuwenhoorn werden in de Romeinse Tijd vier boerderijen op dezelfde plaats, over elkaar, gebouwd. In de oudste inheemse boerderij zijn iep en esdoorn gebruikt voor de dakdragende elementen; in de volgende drie bouwfases is hiervoor vooral eik toegepast. Het vele eikehout bood de mogelijkheid van dendrochronologisch onderzoek. Hiermee kon worden vastgesteld dat de boerderijen respectievelijk in de jaren 57 AD, 62 AD, 86 AD en 107 AD zijn gebouwd. Het eikehout van de opeenvolgende bouwfases is waarschijnlijk uit hetzelfde gebied afkomstig; aanvoer van grote afstand is onwaarschijnlijk. In de laatste bouwphase moesten kennelijk onregelmatiger gegroeid hout gebruiken; wellicht raakte de beschikbare voorraad uitgeput.

Gezien de goede correlatie van de jaarring-patronen met die van eiken van minerale gronden en het ontbreken van correlaties met eiken uit een zeer nat milieu kan worden geconcludeerd dat de eiken van Nieuwenhoorn van zand- of kleigrond afkomstig waren, bijvoorbeeld van oeverwallen langs de Maas. In hoeverre de kleiige Duinkerke I afzettingen al met ruim honderdjarige eiken begroeid waren in de eerste eeuw van onze jaartelling kan niet worden vastgesteld door het ontbreken van pollen-gegevens.

In de inheems-Romeinse vindplaats bij Rockanje konden alleen els en es worden aangetoond, waarbij laatstgenoemde soort werd geprefereerd voor de cruciale constructie-elementen. Een graanschuur in deze vindplaats was geplaatst op zestien elzen palen, die echter wel een dikte van 25 cm of meer hadden.

Het hout van een derde inheems-Romeinse nederzetting, bij Simonshaven, was zeer fragmentair bewaard gebleven door de hogere ligging ten opzichte van de grondwaterstand. Het hoge aandeel van eik in Simonshaven kan vertekend zijn door de grote resistentie tegen afbraak van deze houtsoort.

In de meeste gevallen zijn de resten van de onderzochte voormalige nederzettingen onder de grondwaterspiegel komen te liggen tijdens of na de bewoning. Hierdoor is veel organisch materiaal door afwezigheid van zuurstof gevrijwaard gebleven van biologische afbraak-processen. Naast hout konden ook zeer veel zaden en andere plantendelen in onverkoalde toestand bewaard blijven.

Het onderzoek van de vele onverkoalde zowel als van de minder talrijke verkoalde plantaardige macroresten heeft een scala gegevens opgeleverd die een aanvulling en een uitbreiding vormen van het pollen-onderzoek.

De ligging van de Vroege- en Midden-IJzertijd-vindplaatsen in een rietveen-gebied komt ook bij het zadenonderzoek duidelijk naar voren. De Late-IJzertijd-bewoning bij Rockanje en de Romeinse bij Nieuwenhoorn hadden zich gevestigd in een door veenmos en heide gedomineerde hoogveen-vegetatie. Ook hier wijst de talrijk voorkomende gagel op oxydatie en ontwatering. Dit zal een van de belangrijkste oorzaken zijn, waardoor het daarvoor zeer natte veen bewoonbaar werd geacht.

Een in korte tijd opgebrachte ophogingslaag in Nieuwenhoorn diende mogelijk om klink door compactie van de ondergrond te compenseren.

De Romeinse bewoning bij Rockanje lag op een hoog deel van een kwelderlandschap, waar gedurende een groot deel van het jaar zoet water kon voorkomen. Slechts sporadisch zal de zee nabij geweest zijn. Er werden lage terpjes opgeworpen om de nederzetting tegen overstroming te beschermen.

Bij de macroresten konden ook allerlei resten van gekweekte voedselgewassen en van verzamelde planten worden aangetoond. In vrijwel alle IJzertijd-vindplaatsen treden de granen emmertarwe en vierrijige gerst op, aangevuld met gewassen met olierijke zaden, lijnzaad en/of huttentut. Twee Vroege-IJzertijd-vindplaatsen wijken sterk af van dit beeld. In Rotterdam-Hartelkanaal zijn in het geheel geen verkoalde of onverkoalde resten van voedselplanten gevonden. Het enige wat aan graan aan ons is overgeleverd zijn de indrukken van gerst-korrels in aardewerk.

In de Vroege-IJzertijd-vindplaats Spijkenisse 17-30 werd geen gerst aangetroffen. Naast emmertarwe is hier ook een beperkte hoeveelheid gierst aangetoond. De oliehoudende gewassen lijnzaad en huttentut ontbreken eveneens, raapzaad treedt er voor in de plaats. Het soortenspectrum van cultuurgewassen van de derde Vroege-IJzertijd-vindplaats (Spijkenisse 17-35) sluit aan op het normale patroon van de Midden- en Late IJzertijd.

Het arsenaal cultuurgewassen van de inheems-Romeinse nederzetting bij Nieuwenhoorn vertoont een veel groter aandeel van gerst en een bescheiden rol van emmertarwe, lijnzaad en huttentut. Naast deze gewassen is een aantal tuinbonen gevonden. In de Romeinse nederzetting bij Rockanje is vrijwel uitsluitend vierrijige gerst aangetroffen.

Opvallend is dat alle aangetroffen akkeronkruiden soorten zijn van akkers die in het voorjaar ingezaaid worden (zomergraan-akkers). Kenmerkende soorten van in het najaar ingezaaide akkers ontbreken volledig.

Het ontbreken van wintergraan-akkeronkruiden en de ontbossing van oeverwallen tijdens de IJzertijd zonder dat het hout op grote schaal voor bouwhout is gebruikt, wijzen op het aanleggen van akkers op deze oeverwallen. Doordat ze 's winters regelmatig overstromen, wordt de vruchtbaarheid van de bodem steeds hersteld, maar is het niet mogelijk wintergraan te verbouwen. Na de vorming van Duinkerke I afzettingen boden deze kleiige gronden een enorme uitbreiding van het potentiële akkerland. Op de zware kleigronden, zoals die bijvoorbeeld bij Rockanje voorkwamen, treden tegenwoordig ook in wintergraan-akkers uitsluitend zomergraan akkeronkruiden op. Voor Rockanje kan zaai van wintergraan dan ook niet volledig worden uitgesloten. Experimenten in hedendaagse kwelder-omstandigheden tonen echter, dat ook daar het risico van overstroming in de winter groot is, zodat waarschijnlijk ook op deze gronden in hoofdzaak zomergewassen werden geteeld.

Met behulp van cluster-analyses kon worden gedemonstreerd, dat de zadenmonsters genomen binnen een vindplaats onderling meer overeenkomst vertonen dan monsters genomen in verschillende vindplaatsen. De ecologische factor saliniteit is hierbij de sleutelfactor gebleken. Bij de cluster-analyse op basis van uitsluitend de cultuurgewassen is er een grotere overeenkomst tussen de diverse vindplaatsen, wat in nog sterkere mate geldt voor de cluster-analyses op basis van akkeronkruiden en van al het verkoolde materiaal.

Opmerkelijk zijn de grote verschillen die optreden in het aandeel van akkeronkruiden en graslandplanten in de onderzochte vindplaatsen. In de nederzettingen uit de Vroege en Midden-IJzertijd zijn graslandplanten duidelijk in de meerderheid; in de loop van de tijd treedt een toename van akkeronkruiden op. In het Romeinse Rockanje hebben laatstgenoemden duidelijk de overhand. Het aandeel van graslandplanten wordt geacht verband te houden met het belang van veeteelt in de voedsel-economie, met name in verband met hooi voor wintervoer voor het vee. Graslandplanten zijn echter systematisch ondervertegenwoordigd in nederzettingen, zodat er geen één op één relatie bestaat tussen het aandeel van graslandplanten en het belang van veeteelt.

Het aandeel van wilde planten die voor voedseldoeleinden zijn verzameld, is zeer gering. Slechts enkele zaden van sleedoorn, braam-soorten, roos en vlier zijn aangetroffen. Daarnaast is blijkens een concentratie in een haard uit de Midden-IJzertijd ook mannagras verzameld.

Faunaresten uit vindplaatsen uit de IJzertijd en de Romeinse

Tijd op Voorne-Putten zijn onderzocht door Dr. W. Prummel en Drs. P.J. van Mensch. Doordat de bewoningsresten vaak in venige sedimenten bewaard zijn gebleven, is de conservering van bot, in tegenstelling tot die van de botanische resten, in de regel niet zo goed. Hierdoor leveren de individuele vindplaatsen te weinig gegevens op voor een coherent beeld. Het botmateriaal is daarom per periode gegroepeerd.

In de drie fasen van de IJzertijd zowel als in de Romeinse Tijd is de jachtcomponent verwaarloosbaar; slechts in de Late IJzertijd lijkt steur-visserij van enig belang voor de voedselvoorziening te zijn geweest. Het overgrote deel van de botresten is afkomstig van gedomesticeerde dieren. In de IJzertijd is het rund verreweg de belangrijkste vleesleverancier geweest. Of ook met melkproductie moet worden gerekend, is niet goed vast te stellen. Na het rund wordt de tweede plaats ingenomen door schaap/geit. Waar nader determineerbare resten voorhanden waren, betrof het steeds schaap. Het varken is de volgende soort op de ranglijst. Resten van hond en paard zijn ook regelmatig aangetroffen, maar door het ontbreken van snijsporen op de botten moet worden aangenomen dat ze niet voor het vlees werden gehouden. Het paard zal als rijdier zijn benut, waarbij een status-functie ook zeker niet moet worden genegeerd. Honden kunnen hun diensten hebben bewezen als waak-dieren en bij het hoeden van schapen.

Faunaresten uit de Romeinse Tijd zijn in veel beperktere mate onderzocht. Er lijkt zich evenwel een toename van het aandeel van schapen en/of geiten af te tekenen. Dit zou echter het gevolg kunnen zijn van gunstigere conserverings-omstandigheden. Het rund blijft het belangrijkste slachtvee.

Bij de reconstructie van de voedsel-economie is getracht te bepalen of men zelfvoorzienend geweest kon zijn of niet. Hierbij is het van belang te weten welke eisen de aangetroffen voedselgewassen en huisdieren stellen aan het milieu. Naast dergelijke gegevens op grond van tegenwoordige criteria kunnen paleo-botanische gegevens worden gebruikt om een uitspraak te doen over lokale teelt versus import van bepaalde voedselgewassen. Op de veengronden rond de nederzettingen uit de Vroege en Midden-IJzertijd kunnen mogelijk de graangewassen gerst en gierst verbouwd zijn, emmertarwe zeer waarschijnlijk niet. De diverse gewassen met olierijke zaden konden waarschijnlijk niet op veen verbouwd worden; voor huttentut moet in dit opzicht echter een slag om de arm gehouden worden. Er treedt hier namelijk een discrepantie op tussen paleo-botanische en hedendaagse gegevens. Experimentele verbouw van de IJzertijd-cultuurgewassen op veengrond zou een belangrijke bijdrage kunnen leveren in deze. Ook waar het de granen betreft kunnen hiermee belangrijke inzichten verworven worden.

De botanische macroresten kunnen gegevens opleveren over teelt door de bewoners van de nederzetting versus

import. Van de gewassen gerst, lijnzaad en huttentut leveren bij-produkten van het dorsproces ("afval") in dit opzicht relevante informatie. Voorwaarde hierbij is, dat voldoende monsters uit zoveel mogelijk verschillende context-typen zijn onderzocht.

In het geval van emmertarwe moet geconstateerd worden, dat de bij-produkten die blijkens etnografisch onderzoek wijzen op lokale teelt, met name de grotere stengelfragmenten en de stengelknopen, zelden worden aangetroffen in paleo-botanisch onderzoek. Ook in een producerende nederzetting komen geen stengelfragmenten terecht. Kafresten van emmertarwe kunnen ook in het afval van importerende nederzettingen worden aangetroffen. Hierdoor is het niet mogelijk lokale productie of import van emmer aan te tonen.

Van het vee wordt aangenomen dat het bij de boerderijen werd gehouden. Dit wordt zowel door de vaak aanwezige stalboxen als door de veelal dikke mestpakketten aangetoond. De belangrijkste vleesleverancier, het rund, kan zijn geweid in de rietvegetaties rond de nederzettingen. Ook tijdens de Late IJzertijd en de Romeinse Tijd zullen dergelijke rietvegetaties in de nabijheid van de nederzettingen hebben gelegen. Uit recent begrazingsonderzoek in de Oostvaardersplassen is het eten van riet door rundvee als reële mogelijkheid naar voren gekomen. Door deze begrazing ontstaan vegetatie-typen met lagere kruiden, die ook door schapen begraasd kunnen worden. Naast schapen werden waarschijnlijk ook enkele geiten gehouden. Elliptische uitwerpselen met vrijwel uitsluitend resten van de lokaal aanwezige gagel zijn waarschijnlijk geproduceerd door geiten.

De drie opgegraven boerderijen uit de Vroege IJzertijd tonen een opmerkelijke ontwikkeling. In Rotterdam-Hartelkanaal is het bouwhout zeer weinig duurzaam. Daarnaast ontbreken cultuurgewassen en akkeronkruiden in de zadenmonsters, die echter minder stelselmatig zijn verzameld als op de andere besproken opgravingen. In Spijkenisse 17-30 is duurzamer hout verwerkt. Het assortiment cultuurgewassen wijkt door de aanwezigheid van gierst en raapzaad en de afwezigheid van gerst af van de derde Vroege-IJzertijd-boerderij, Spijkenisse 17-35 en van de Midden- en Late-IJzertijd-boerderijen. Bovendien zijn in 17-30 geen aanwijzingen voor de lokale verbouw van cultuurgewassen, noch komen specifieke akkeronkruiden voor. In Spijkenisse 17-35 is gerst, lijnzaad en huttentut door de bewoners verbouwd en gedorst. Tevens zijn in 17-35 een aantal specifieke zomergraan-akkeronkruiden aangetroffen.

De drie nederzettingen zijn op grond van deze botanische gegevens goed in te passen in een model, dat is ontwikkeld voor veenbewoning in de Assendelver Polders door Brandt *et al.* (1984). Volgens dit model wordt een voorheen onbewoond veengebied eerst door korte bezoeken verkend. Dan wordt het gebied benut voor het weiden van vee gedurende

de zomer. De bewoning is niet permanent en er wordt geen akkerbouw bedreven. Deze fase kan mogelijk door Rotterdam-Hartelkanaal zijn vertegenwoordigd. Vervolgens treedt een fase op, waarbij men zich wel permanent in het gebied vestigt, maar zich alleen toelegt op veeteelt. Akkerbouw-producten worden via ruilhandel met verwanten verkregen. Spijkenisse 17-30 zou deze fase kunnen representeren. Tenslotte zou ook akkerbouw worden bedreven door de veenbewoners, die daarmee terugkeren naar een zoveel mogelijk zelfvoorzienende economie. Deze fase wordt mogelijk vertegenwoordigd door de vindplaats Spijkenisse 17-35.

In alle onderzochte vindplaatsen uit de Midden-IJzertijd lijkt men zowel akkerbouw als veeteelt bedreven te hebben. Het bewoningshaat tussen de Vroege en de Midden-IJzertijd heeft niet aantoonbaar tot hernieuwde staps-gewijze kolonisatie van het gebied geleid. Als dit ook na onderzoek van meer nederzettingen uit de Midden-IJzertijd het geval blijft, moet geconcludeerd worden dat het agrarische potentieel van het gebied na een bewoningshaat van ongeveer een eeuw nog steeds bekend was.

De vondst van een concentratie verkoolde zaden van mannagras in een haard van de Midden-IJzertijd-boerderij Spijkenisse 17-34, tesamen met diverse verkoolde cultuurgewassen, toont aan dat dit gras tot voedsel diende. Tot in de 18^e eeuw werd dit gras voor consumptie verzameld. Kennelijk kon de energie-behoefte in de Midden-IJzertijd bij Spijkenisse niet steeds volledig door graan gedekt worden.

De Late IJzertijd volgt zonder haat op de Midden-IJzertijd. Ook in deze fase is sprake van een zelfvoorzienende voedselproductie. Het landschap levert in dit opzicht geen beperkingen meer op door de kleine afzettingen van Duinkerke I rond de Bernisse.

In de Romeinse Tijd lag bij Nieuwenhoorn een boerderij uit de eerste en begin tweede eeuw van onze jaartelling. Tarwe is hier van ondergeschikt belang, evenals lijnzaad en huttentut. Gerst is het belangrijkste cultuurgewas, veld- of duivebonen werden eveneens gekweekt. Bij Rockanje werd in de 2^e/3^e eeuw in een kweldermilieu vrijwel uitsluitend gerst verbouwd. Hoewel ook huttentut en veld- of duiveboon in een dergelijk milieu met succes gekweekt kunnen worden, ontbreken deze gewassen volledig. Er lijkt sprake van een gespecialiseerde akkerbouw.

Nadat is vastgesteld welke cultuurgewassen mogelijk door de bewoners van de nederzettingen werden gekweekt en welke dieren aan de voedselvoorziening bijdroegen, is getracht te bepalen of men geheel in de eigen voedselbehoefte kon voorzien.

Met behulp van de geschatte vlees- en melkproductie op basis van het aantal stalboxen is berekend welk deel van de calorie- en eiwitbehoefte kan zijn geleverd door dierlijke producten. Voor de IJzertijd zijn als model boerderijen met zes en met tien stalboxen gekozen. Voor beide boerderijen

wordt het aantal inwoners geschat op vier en zes. De lage schatting is naar aanleiding van de oppervlakte van het woondeel, waarbij is aangenomen dat een persoon 10 m² heeft. De hogere schatting is op basis van een vaak in de literatuur terugkerende aanname.

In de boerderij met zes stalboxen kunnen dierlijke produkten in 47-67% van de energiebehoefte van een model-familie met vier inwoners hebben voorzien. De overige calorieën zullen hoofdzakelijk door graan zijn geleverd. Hiermee zal ook de eiwitbehoefte zijn gedekt. Als de boerderij met zes stalboxen door een model-huishouden van zes personen plus een baby bewoond werd, wordt in 31-44% van de energiebehoefte voorzien door dierlijke produkten. De hoeveelheid graan die vereist is om de calorie- en eiwitbehoefte te dekken, kan door maximaal 3 ha akkerland opgebracht worden.

In de hypothetische boerderij met tien stalboxen kan 58-84% van de energiebehoefte van vier inwoners door dierlijke produkten worden geleverd. In het model voor zes inwoners met baby wordt 38-54% van de vereiste calorieën geleverd. In dit geval is maximaal 2.5 ha graanland vereist.

De bewoners van Rotterdam-Hartelkanaal, met zes stalboxen, moeten derhalve plantaardige produkten gegeten hebben om in hun energiebehoefte te voorzien. De hiervoor geopperde import van graan verplicht de bewoners relaties te onderhouden met een graanoverschot producerende gemeenschap. Ook de bewoners van Spijkenisse 17-30 zullen graan, in dit geval emmer, hebben moeten importeren, dan wel het zelf hebben verbouwd op de oeverwallen langs de Maas. Doordat gewassen, waarvan eigen productie aantoonbaar is in deze vindplaats ontbreken, is er geen keuze mogelijk tussen deze alternatieven.

In Spijkenisse 17-35 en in de Midden-IJzertijd-vindplaatsen zijn wel duidelijke aanwijzingen voor verbouw van cultuurgewassen door de bewoners, die in hoofdzaak zelfvoorzienend geweest zullen zijn. Aangezien van de granen alleen gerst is aangetroffen in de Vroege-IJzertijd-monsters van 17-35, is teelt nabij de nederzetting niet uitgesloten. Voor de in de Midden-IJzertijd talrijke emmer is teelt op veen echter onwaarschijnlijk. Omdat deze nederzettingen net als die van Spijkenisse 17-30 op enkele kilometers van de goede akkerbouwgronden langs de Maas lagen, zal deze afstand geen onoverkomelijk probleem opgeleverd hebben. Ook in hedendaagse, niet gemechaniseerde samenlevingen blijkt een dergelijke afstand goed overbrugbaar. De ligging van alle nederzettingen langs kreken zal in het bulk-transport van graan van wezenlijk belang zijn geweest.

In de Late IJzertijd kon de agrarische produktie dicht bij de nederzettingen plaatsvinden. De zandig tot kleiige Duinkerke I afzettingen rond de Bernisse boden ruimte aan tientallen zelfvoorzienende IJzertijd-boerderijen.

Op grond van het aantal bekende nederzettingen kan worden vastgesteld, dat er waarschijnlijk slechts enkele

gelijktijdige boerderijen waren in de IJzertijd. Het aantal inwoners van het gebied was dermate klein, dat ondanks een zelfvoorzienende voedsleconomie en de aanwezigheid van voldoende potentieel akkerland, toch banden moeten hebben bestaan met andere bevolkingsgroepen. Op grond van aarde-werk-overeenkomsten moet hier vooral aan de Oude Duinen en/of de oeverwallen langs de Maas worden gedacht.

In de Romeinse Tijd zijn de duidelijke stalboxen uit de IJzertijd-boerderijen niet meer herkenbaar. Op grond van de grootte van de betreffende inheemse boerderijen en de aanzienlijke hoeveelheid mest in de ophogingslagen, met name in Nieuwenhoorn, kan worden aangenomen dat veeteelt een belangrijk onderdeel van de bedrijfsvoering uitmaakte. Het aantal bewoners van de boerderijen was mogelijk groter dan in de IJzertijd, naar schatting zes tot acht personen. Door de grootte kon zeker zoveel vee gehuisvest worden als in de IJzertijd-boerderij met tien stalboxen. Bij zes inwoners kan derhalve weer in 38-54% van de caloriebehoefte worden voorzien door dierlijke produkten, bij acht inwoners kan dit aandeel 25-36% geweest zijn.

De graanschuren die zijn gevonden bij de inheems-Romeinse nederzettingen bij Rockanje en Simonshaven hebben een dermate grote inhoud, dat veel meer dan de graanbehoefte voor één jaar van een gezin kon worden opgeslagen. Indien er een 30-35 cm hoog muurtje op de vloer van de schuren stond, kon ruim 7000 kg gerst voor consumptie worden opgeslagen. Aangenomen wordt, dat deze hoeveelheid niet diende om misoogsten in een aantal opeenvolgende jaren op te vangen, maar dat het een surplus was, dat voor levering aan derden diende.

Berekeningen van de benodigde hoeveelheid land in de diverse modellen toont aan, dat in de IJzertijd zowel voor weide- als voor hooiland ruim voldoende kruidige rietvegetaties beschikbaar waren. De oeverwallen langs de Maas kunnen akkerland voor tientallen (zelfvoorzienende) IJzertijd-boerderijen geboden hebben. Het geschatte aantal gelijktijdige IJzertijd-boerderijen in het veengebied is met maximaal zes, gedurende de Midden-IJzertijd, ver beneden de draagkracht van het gebied. In de Late IJzertijd kan het grote klei-gebied van Duinkerke I afzettingen rond de Bernisse zelfs ruimschoots in het akkerland van honderd gelijktijdige nederzettingen hebben voorzien.

In de Romeinse Tijd is een veel groter graanareaal vereist om het berekende surplus te produceren. Bij een voorzichtige inschatting van een braak-periode van om het jaar is ca. 29-34 ha nodig om een graanschuur te vullen. Het gebied rond de Bernisse kan in de Romeinse Tijd plaats bieden aan 21-25 gelijktijdige boerderijen, op voorwaarde dat het vee geweid werd in de veengebieden. Naar schatting waren er 30 gelijktijdige inheems-Romeinse nederzettingen rond de Bernisse, zodat niet in alle een graanschuur ter grootte van die van Simonshaven en Rockanje vol kon worden geproduceerd. Het veel grotere kleidek op westelijk Voorne zal geen

beperkingen hebben geboden, te meer daar hier waarschijnlijk ook minder nederzettingen lagen.

Na de beschikbare hoeveelheid land is geschat of de hoeveelheid te verrichten arbeid een beperkende factor kan zijn geweest in de diverse modellen. Voor wat betreft het maaien van rietvegetaties voor wintervoer moest men ongeveer een maand werk voor één persoon uittrekken. Na de graanoogst zal deze benodigde tijd beschikbaar zijn geweest. Voor wat het graan betreft, hangt alles van de zaaimethode af. Aangenomen wordt, dat in de IJzertijd de arbeidsintensieve zaaimethode op rijen werd toegepast. Hiervoor zal gedurende de IJzertijd maximaal 3 ha benodigd zijn geweest. Het cruciale punt voor de IJzertijd-graانvoorziening zal het oogsten zijn geweest, wat binnen een maand diende te geschieden. Het oogsten van drie hectare zal wellicht 60 mens-dagen gekost hebben. Hiermee kunnen twee personen in een maand juist al het benodigde oogsten.

Deze berekeningen hebben belangrijke implicaties voor het model omtrent de kolonisatie van veengebieden. De maximaal oogstbare 3 ha kan namelijk in de voedselbehoefte voorzien van een bevolking, die voor een belangrijk deel van veeteelt leeft. Als wordt aangenomen, dat de bewoners van Rotterdam-Hartelkanaal en van Spijkenisse 17-30 hun graan van in akkerbouw gespecialiseerde verwanten betrokken, treden er aanzienlijke complicaties op. Deze akkerbouwers zouden namelijk niet alleen in hun eigen graanbehoefte moeten voorzien, maar ook in die van de veeteelt bedrijvende veenbewoners. Dit betekent dat ze tenminste zes hectare moesten bewerken. Dit kan alleen mogelijk zijn geweest, als ze bij de cruciale bewerkingen, vooral bij het oogsten, hulp kregen van de veenbewoners. Het verschil met het alternatief, akkerbouw door de veenbewoners zelf in de vroege ijzertijd op de enkele kilometers ver gelegen oeverwallen, wordt daarmee wel heel klein. De economie van de veenbewoners bevond zich derhalve in het niet meer onderscheidbare overgangsgebied tussen uitwisseling plus hulp bij de oogst en zelfvoorziening.

De berekeningen voor de Romeinse Tijd leverden op, dat 14-17 ha op rijen gezaaid graan vereist waren, om een graanschuur te vullen. De oogst zal in dit geval de inzet van ongeveer tien arbeidskrachten gedurende één maand vereist hebben, terwijl de inheems-Romeinse boerderijen waarschijnlijk zes tot acht inwoners telden. Op rijen zaaien was derhalve onmogelijk. De oogst na breedwerpig zaaien zou 150-180 werkdagen vereisen, omdat in dat geval hetzelfde oogstgewicht van een kleinere oppervlakte verkregen kan worden. In dit geval zijn vijf tot zes arbeidskrachten vereist. Dit is aan de bovengrens van het haalbare. Van de hoeveelheid die in een graanschuur kon worden opgeslagen, moet nu echter een groter deel voor uitzaai in het volgende jaar worden gereserveerd. Het resterende surplus kan aan het Romeinse leger geleverd zijn. In dat geval kunnen elf soldaten van graan worden voorzien. Deze hoeveelheid kon worden geleverd door een huishouden met maximaal acht personen.

Er wordt verondersteld, dat de overgang van de IJzertijd naar de Romeinse Tijd belangrijke gevolgen heeft gehad voor de autochtone bewoners. Groenman-van Waateringe onderscheidt een aantal fasen van aanpassing van de voedsel-economie. Tijdens de veroverings-campagnes zal het voedsel vanuit al eerder bezet gebied zijn aangevoerd. De lokale produktie zal zowel kwantitatief als kwalitatief niet aan de eisen hebben voldaan. Met name het feit dat de legioenen vrijwel uitsluitend tarwe, en geen gerst, zouden consumeren, wordt door Groenman-van Waateringe benadrukt. De tweede fase in de overschakeling is de aanpassing van de lokale produktie aan de militaire behoefte; deze fase wordt geacht tot het begin van de tweede eeuw geduurd te hebben. Daarna volgde tot de tweede helft van de derde eeuw een periode van stabilisatie. Vervolgens treedt door bodem-uitputting en erosie een daling van de produktie op; het graan voor de Romeinse legioenen moest per schip van Groot-Britannië worden aangevoerd.

In dit licht kunnen de twee onderzochte inheems-Romeinse nederzettingen op Voorne-Putten worden gezien. Zowel Nieuwenhoorn, daterend uit de eerste tot begin tweede eeuw, als Rockanje, uit de tweede helft van de tweede en de eerste helft van de derde eeuw, blijken in hoofdzaak gerst geproduceerd te hebben. Met name in het geval van Rockanje lijkt men zich gespecialiseerd te hebben in dit gewas. Er is geen overschakeling naar tarwe aantoonbaar. In het zoute milieu rond Rockanje kan tarwe ook niet geproduceerd zijn. De mogelijkheid bestaat, dat het overschot aan gerst niet door de Romeinse soldaten werd geconsumeerd. Als alternatief kunnen de paarden dienen die blijken de aanwezigheid van cavalerie-afdelingen in de Romeinse *castella* zeker talrijk aanwezig waren. Ten tweede kunnen de bewoners van Rockanje zelf paarden gefokt hebben voor de legioenen.

Kwantitatieve veranderingen bij de overgang van de IJzertijd naar de Romeinse Tijd worden zeer duidelijk aangetoond door de grote graanschuren met een opslagcapaciteit ver boven de behoefte van een huishouden. De in de Romeinse Tijd optredende diversiteit in huis-plattegronden wijst op specialisatie op agrarisch gebied. Kwalitatieve veranderingen zijn echter niet aantoonbaar.

Dit onderzoek was mogelijk door de bijzonder goede conservering van organisch materiaal op Voorne-Putten. Deze conservering treedt niet op als de resten onder aanwezigheid van zuurstof afgebroken worden. In dat geval kan alleen verkoold materiaal de tand des tijds doorstaan. Kunstmatige verlaging van de grondwaterstand voor agrarische doeleinden dreigt echter door de ermee gepaard gaande oxydatie een verwoestende en onomkeerbare uitwerking te hebben op de sinds duizenden jaren in het bodemarchief bewaard gebleven nederzettingen, en daarmee op de mogelijkheid van gedetailleerd archeologisch en oecologisch onderzoek.

list of abbreviations

B.O.O.R.	Bureau Oudheidkundig Onderzoek van Gemeentewerken Rotterdam.
I.P.L.	Instituut voor Prehistorie Leiden.
I.P.P.	Instituut voor Prae- en Protohistorie, Amsterdam.
R.O.B.	Rijksdienst voor het Oudheidkundig Bodemonderzoek, Amersfoort.
N.W.O.	Nederlandse Organisatie voor Wetenschappelijk Onderzoek.
cf.	<i>confer</i> , identification uncertain.
ha	hectare (10,000 m ² , ca. 2.47 acres).
m	metre(s).
kcal	kilocalorie(s); 4.18 KJoule.
N.A.P.	Normaal Amsterdams Peil (Dutch Ordnance Datum).
÷	below.
Ab.	Abbenbroek.
Gv.	Geervliet.
Nh.	Nieuwenhoorn.
Ro.	Rockanje (08-52).
Rock.	Rockanje II.
Sp.	Spijkenisse.
Zl.	Zuidland.

abbreviations/symbols used in tables

gl.b.	glume base.
sp.f.	spikelet fork.
intern.	rachis internode.
?	identification uncertain.
indet.	<i>indeterminatae</i> .

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